Strategic forest planning using AHP and TOPSIS in participatory environments

A case study conducted in Vilhelmina, Sweden

Strategisk skogsbruksplanering med hjälp av AHP och TOPSIS i deltagande miljöer.

En fallstudie utförd i Vilhelmina, Sverige

Hilma Nilsson

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Sammanfattning

Den strategiska skogsskötseln i Sverige planeras ofta med en hundraårig planeringshorisont. För att den ska anses hållbar bör den ta hänsyn till andra mål än produktion, såsom sociala värden och rennäring. Heureka PlanVis är ett avancerat datasystem för långsiktiga skogliga analyser och med dess hjälp kan strategiska skötselplaner tas fram. Olika beslutsstöd för att välja den plan mest lämplig för de givna målen, t.ex. olika Multiple Criteria Decision Analyses (MCDA), har utvecklats och testats med goda resultat. De har dock alla en svaghet som består i att beslutsfattaren inte har möjlighet till att studera hela spekrat av möjliga planer, utan begränsas ofta till 2-4 planer. Syftet med denna studie var att undersöka tillämpbarheten av att kombinera två olika MCDA–verktyg: ”the Technique for Order Preference by Similarity to Ideal Solution” (TOPSIS) och ”the Analytic Hierarchy Process” (AHP) för att ta hänsyn till multipla mål inom strategisk skoglig deltagande planering. Först skapades ett flertal möjliga skötselplaner med Heurekas Planvis applikation. Därefter användes AHP för att beräkna vikterna på de kriterier som ansågs definiera de givna målen, vikterna implementerades därefter i TOPSIS från vilken planerna kunde rangordas efter hur väl de uppfyllde de givna målen. Resultatet visade att kombinationen av AHP och TOPSIS är enkelt att praktiskt implementera i en deltagande skogbruksplanering och att beslutsfattaren kunde utnyttja Heureka Planvis fulla kapaciteten att skapa många skogsskötselplaner och därmed grunda sitt beslut på ett bredare spektra av planer än vad tidigare varit möjligt.

Nyckelord*:* multiple criteria decision analyses, technique for order preference by similarity to ideal solution, analytic hierarchy process, Heureka, mål, deltagande planering, skogsskötsel, strategisk

Abstract

When a decision is to be made on what long term strategic forest management plan to use, consideration must often be taken to multiple objectives. Such decisions are very complex and a promising approach to handle them is by Multiple Criteria Decision Analyses (MCDA). The study is based on the problem that the MCDA that have been implemented into forest management planning have only had capacity to compare and evaluate a limited number of management plans; which means that there is a risk the most suitable plan is missed. The aim with this study was to test the applicability of combining the MCDA tools: the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and the Analytic Hierarchy Process (AHP) for including consideration to multi-objectives into strategic forest management planning. The study was based on the process of creating and selecting a management plan, using Heureka PlanWise, suitable for all the major objectives found in the forest holdings of a municipality in northern Sweden. AHP was used to get the weights on the criteria defining the given objective, which then was implemented in TOPSIS in order to get the plans ranked depending on how well they fulfilled the given objective. The result showed that the combination of AHP and TOPSIS is practically easy to implement into a participatory forestry planning and that the full capacity of Heureka PlanWise's ability to create numerous of management plans could come forward, which in turn reduced the chance that the optimal plan is missed.

Keywords: multiple criteria decision analyses, Heruka Planwise, Heureka Planeval, analytic hierarchy process, technique for order preference by similarity to ideal solution, multiple objective, participatory planning, forest management, strategic

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Umeå, February 2014

Hilma Nilsson

Contents

1 Introduction

This study focus on the long term decision making regarding management strategies set for large forest holdings: giving special notice to the decisions made with the presence of multiple objectives, a scenario which particularly manifests itself when multiple stakeholders are involved in the decision making process.

1.1 Background to problem

Different sorts of software have been designed to simulate strategic[1] management plans that are adapted to the dynamic shift of the forest landscape. An example of such software is Heureka PlanWise, developed by the Swedish University of Agricultural Science. It can be used to create numerous management plans for a forest estate or landscape, and with the help of its treatment simulator and optimizer they can all be orientated towards different objectives. By analyzing the characteristics of the plans by PlanWise the most suitable for the overall objective can be selected by those involved in the decision making process (SLU, 2013a). However, before this selection may occur, the overall objective and the definition of its fulfillment have to be distinguished. Economic values tend to dominate among forest objectives, but they may be more or less balanced with diverse ecological and social values; resulting in making "multiple objectives" a term closely related to forest management (e.g. Xu & Bengtson, 1997). Multiple objectives particularly manifests itself when multiple stakeholders are involved in the decision making process. Public authorities in Sweden, owning forests, must base their forest management on the public's interest. The process of determining the multiple objectives given by the public can be helped by a participatory planning approach (e.g. Nordström et al., 2010; Sheppard & Meitner, 2005; Kangas & Store, 2002); which is also encouraged by worldwide certifications such as the Forest Stewardship Council (FSC, 1996). When the objectives are given it remains to define the fulfilment of them; meaning we must be familiar with their characteristics. Knowing if an economic value is fulfilled or not can easily be found out by looking at the financial outcome of a plan. The same straightforward derivation of satisfaction of an objective can normally not be made with ecological nor social values. They are better defined by multiple forest criteria (such as the presence of a certain tree species, the existence of certain forest structures etc.) (Axielle, 2013; Edwards et al., 2011; Kangas et al., 2008). The conclusion drawn by this is that the forest management planning is just not handling multiple objectives; but multiple objectives defined by multiple criteria.

1.2 Problem

A promising approach of structuring such complex problems as described is by multiple criteria decision analyses (MCDA), which also shows promises in participatory planning processes (e.g. Nordström et al. 2010). Ananda & Herath (2009) describe the MCDA as follows:

- The objectives are defined and the criteria to measure the objectives are chosen
- Alternatives (i.e. management plans) to reach the given objective are specified, all having different impacts on the chosen criteria
- Weights are assigned to the criteria, reflecting their relative importance
- A mathematical algorithm is used to rank the plans according to how well their outcome meets the given objective.

[1] Long term planning, with planning horizons of 50 -100 years (Öhman, 2007)

The weight assignment is often mentioned as the biggest strength with MCDA in participatory planning problems (e.g. Sheppard & Meitner, 2004).

One of the most used techniques in participatory planning for establishing weights on the criteria and evaluating the plans with respect to each objective is the Analytic Hierarchy Process, AHP (Kangas & Kangas, 2005), which was developed by T.L. Saaty in the 1970's (Saaty, 1987). AHP is based on pairwise judgements on the criteria and the alternatives given, from which the alternatives' relative importance can be ranked. AHP has been implemented in Heureka PlanEval (SLU 2013b), which in turn is integrated with the Heureka PlanWise system making its connection with the simulation software strong. However, a weakness often mentioned with AHP is its tendency to quickly grow complex as the number of criteria and alternatives increases[2] (e.g. Zanakis et al., 1998). Given this complexity it is advised that the number of criteria and alternatives, respectively, does not exceed nine (Miller, 1956, cited in Yoon & Hwang, 1995). The number of alternatives (i.e. management plans) simulated by Heureka PlanWise must therefore be limited in order to make the decision process manageable. Not only does this bring a risk that a more suitable plan than the one given by AHP gets sorted out before the actual decision process; to make this culling of management plans also suppress Heureka PlanWise's quality to conduct numerous plans.

Korosuo et al. (2011) encountered a problem, related to a large number of comparisons, where the decision maker simply lost his/her interest and commitment to the task along the way. Another aspect, related to participatory planning, is that it demands good knowledge and understanding on how different treatments affect the forest to be able to compare forest management plans and how they affect the outcome of different criteria (Eyvindson et al., 2010). Kangas (1994) found that the participants in his study found it difficult to make judgements on the given management plans, and where only willing in doing so if they had a special interest in an outcome.

An alternative to use AHP for evaluating the plans is to use the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). TOPSIS was developed by Hwang and Yoon in 1981 and it is a method for MCDA; based on the concept that the chosen alternative should have the shortest distance to the positive-ideal solution and the longest distance from the negative-ideal solution (Hwang and Yoon, 1995). The alternatives are ranked relatively to each other, without any predefined target values to account for[3]. The strength with TOPSIS is that it exceeds the capacity of AHP (as well as other common MCDM such as ELECTRE and SAW) as the number of alternatives increases (Zanakis et al. (1997). This is because there is no need for any judgments directly on the alternatives; the ranking of them is instead based on the criteria's relative importance to each other, meaning there is no need for a subjective selection of a few alternatives (i.e. management plans) in order to make the decision process manageable. The weakness with TOPSIS is that the criteria weights are based on subjective estimations since it is not providing weight elicitation (Shih et al., 2007). Several of authors have combined AHP and TOPSIS in multiple criteria problems; AHP is then used to assign weights to the criteria and TOPSIS is used to calculate the final ranking of the alternatives (e.g. Gao & Hailu, 2013; Dağdeviren et al., 2009). Just as AHP, TOPSIS has been successfully applied to participatory planning processes concerning multiple criteria problems

[2] The number of judgements needed is $m(m-1)/2 * n(n-1)/2$) m = management plans, n= criteria

[3] Target values are a term closely related to goal programming, for further reading please see Lee (1972)

(e.g. Shih et al., 2004). However, TOPSIS has not yet been introduced to forest orientated problems.

The hypothesis in this study is that strategic forest management planning can benefit from the combination of AHP and TOPSIS, especially in those cases where the use of a participatory planning process causes the presence of multiple objectives. This is based on two assumptions:

- To allow an increased number of management plans in the decision process should promote a wider range of the variety between the plans, and will it also reduce the gaps between them; and by that reduce the chance to “miss” the optimal plan.
- To leave out the management plans from the weighting process should make the process more adapted to those without good knowledge in forestry and thereby more adapted to participatory planning.

1.3 Aim

The aim of this study is to examine whether the combination of AHP and TOPSIS is applicable or not for accounting to several objectives, which is given by multiple stakeholders, in strategic forest management planning. The study will be based on a process consisting of defining the multiple objectives given in the forest holdings of a municipality in northern Sweden, creating many diverse management plans, using Heureka PlanWise, and then selecting the one most suitable for the objectives given. If a high number of diverse management plans can be generated and the selection of the most suitable can be done without making the decision process too demanding for the stakeholders; the hypothesis should be true.

2 Material and Method

2.1 Vilhelmina

The study was based on the multiple objectives given in the forest holdings of a municipality in northern Sweden, called Vilhelmina. The productive forest land, 6682 ha, is owned by Vilhelmina municipality and managed by a company called Skogssällskapet. The forest data was available in form of a management plan dated from 2006, covering the forest holdings of Vilhelmina municipality. No general guidelines on how the forest should be managed have been given by the owner, other than a wish of it generating 1 million SEK per year. All other management strategies are basically up to Skogssällskapet to decide[4].

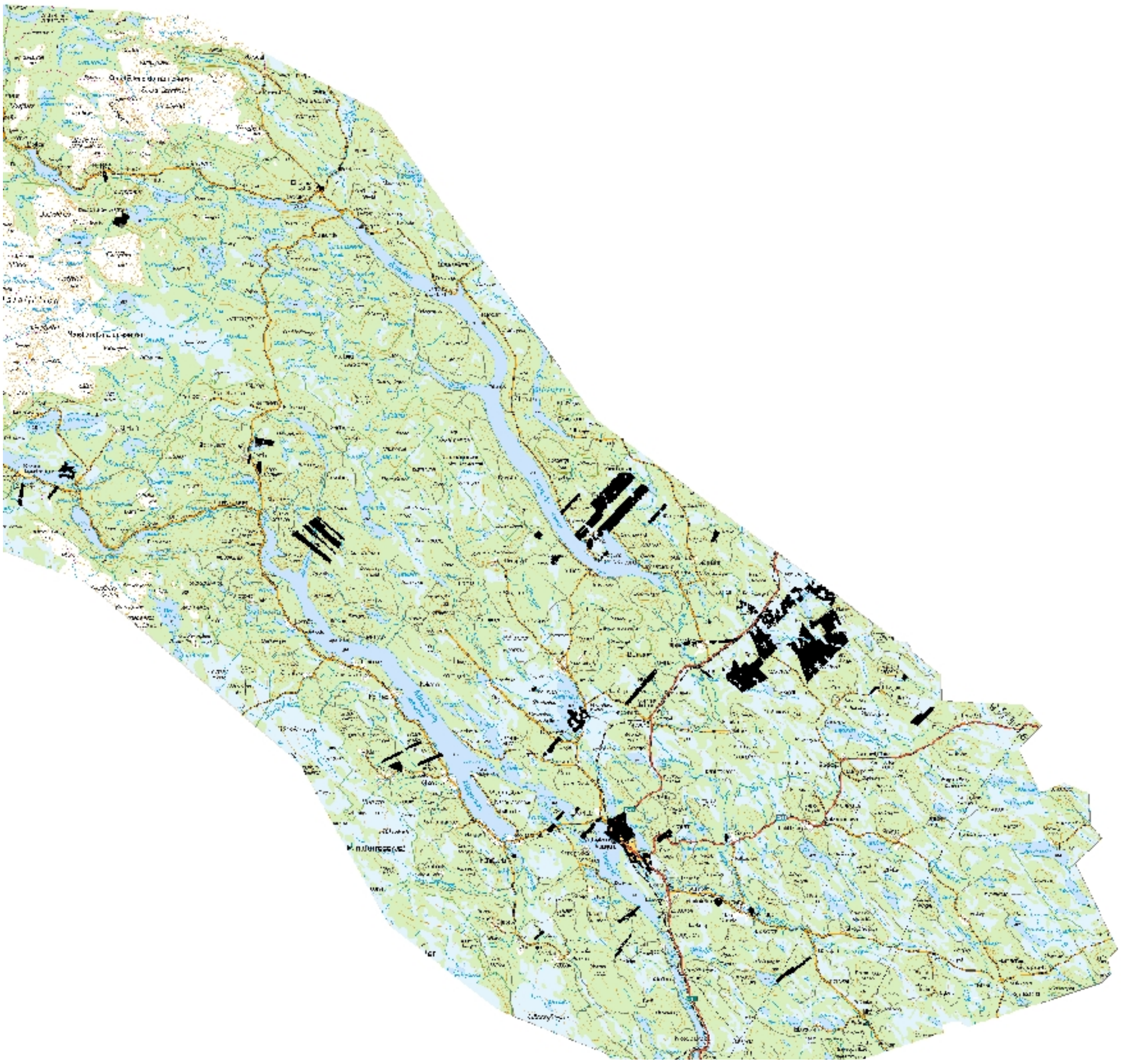

Figure 1. The forest owned by the municipality of Vilhelmina. The outlines of the map are the same as the borders of the municipality and the areas filled with black color are forest areas (tot. 10910 ha) owned by the municipality of Vilhelmina. 6682 ha of the forest land are classified as productive.

[4] Lundgren, Nils; forest manager for Vilhelmina, is working for Skogssällskapet. 2013. Telephone call in September 2013.

As can be seen in Figure 1, the forest owned by Vilhelmina is scattered all over the municipality and it is thereby influenced by many interests. In the urban areas recreation play an important role and is today affecting the forest management in that silvicultural measures dramatically changing the landscape are restricted[5]. Just like all larger forest owners Vilhelmina (or the manager of its forest) is obligated by the Swedish law (SFS 1979:429, 20) to consulate with the Sami villages located within its borders, Vilhelmina Norra and Vilhelmina Södra, before final felling and constructions of new roads in the forest. Ecological interests stretches all over the landscape, and some of the land areas owned by the municipality border to reservations and areas of special ecological interest.

In 2004 Vilhelmina became a part of the international model forest network (IMFN), as Vilhelmina Model Forest (VMF). The purpose of VMF is to obtain a sustainable use of the land within the municipality, which should be based on public participation (VMF, 2013). Due to this commitment there is a well-established network of stakeholders within the municipality with representatives for all landowners as well as other interest groups. VMF also provided a geographic information system (MFGIS), which can be found on their website (VMF, 2013), where areas of national interest and/or of special concern for the reindeer and forest management are rendered in thematic maps.

2.2 MCDA – Multiple Criteria Decision Analysis

The planning process used in this study was based on a MCDA adapted from the works by Nordström et al. (2010), Kangas & Kangas (2004), Yoon & Whang (1995) and Keeney (1982): and consists of five steps:

- Stakeholder analysis
- Identification of goals and interests
- Elicit preference values
- Generating management plans
- Ranking the management plans.

2.2.1 Stakeholder analysis

The objective of the stakeholder analysis is to identify and classify the stakeholders that are affected by or that can affect the situation in some way (Nordström et al. 2010). In this study the analysis was structured using the representative democracy approach, having the stakeholders represented by four interest groups. Each interest group represented an objective that can affect or is affected by the forest management; production, reindeer management, recreation and environment. One to five representatives who could represent the public's opinions were distinguished for each interest group (totally nine individuals from Vilhelmina and two individuals, both scientists, from the Swedish University of Agriculture). In the process of finding relevant representatives VMF and their established network were very helpful.

2.2.2 Identification of goals and interest

The purpose of this step is to identify the connections and contradictions between the interest groups (Nordström et al. 2010). In this study this was done, with the help of interviews, by first identifying the criteria which should define the given objective and then dividing the forest of Vilhelmina in different zones.

[5] Lundgren, N., (2013).

Objective hierarchy

When handling a multiple criteria problem it is advisable to construct a hierarchal model (i.e. objective hierarchy) to ensure that all the criteria are representing the desired objective (Yoon & Hwang, 1995). In general a hierarchical model descends from an overall objective, down to criteria and down further to sub criteria. The criteria and sub criteria may be regarded as intermediate objectives that need to be fulfilled in order for the overall objective to be fulfilled. The overall objective can be decomposed by the interest groups representing the public's will. The interest groups can be given weights describing their influence on the overall objective (e.g. Kangas, 1994 and Nordström et al., 2008). Much as in Nordström et al. (2008), the interest groups in this study represented one objective each, with its own criteria and sub criteria in descending order in the hierarchy (see Fig. 2) (e.g. Saaty, 1987).

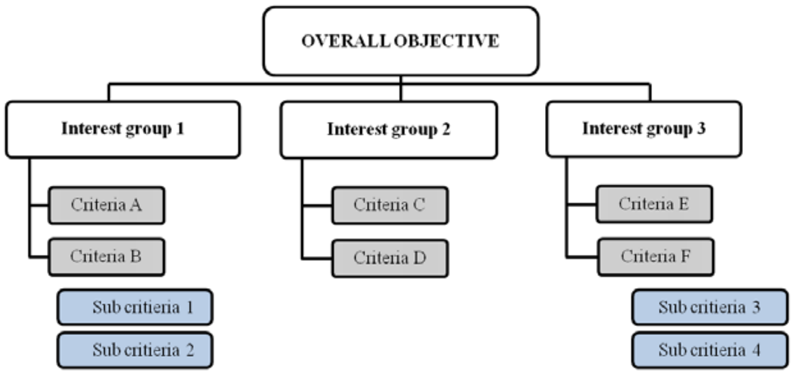

Figure 2.When multiple objectives are included in the decision process, through participatory planning, the overall objective can be decomposed by the interest groups representing the public's will. Much as in Nordström et al. (2008), the interest groups in the figure represent one objective each, with its own criteria and sub criteria in descending order.

All nine stakeholders, with local attachment to Vilhelmina, were interviewed on phone with the purpose of identifying the criteria defining the objective of each interest group. The interviews were semi structured and centred on the criteria often mentioned in the literature as significant for each objective represented. The interview guides used can be seen in Appendix 1. The answers from the interviews were written down and analysed with the purpose of creating an objective hierarchy. The finished hierarchy was e-mailed to each stakeholder for them to evaluate if they found it truly reflecting their interest group's objective.

Zone classification

When Nordström et al. (2008) and Kangas (1994) investigated multiple objectives in forest areas they used prepared, thematic maps rendering questions of special interest in their studies. These were used as a support for the discussions held about the objectives of the participants. Based on these studies, thematic maps covering the forest holdings of Vilhelmina were created. The forest was classified into four different management zones; a zone with no commercial cutting, a zone with prolonged rotation, a zone with no treatment and a zone with commercial cutting. The classification was based on data provided by the management plan and a map giving a geographic overview of the municipality, and was thereby based on both spatial (e.g. closeness to village) and non-spatial features (e.g. management class). With the help of the MFGIS special notice was also made to stands located in areas perceived as extra important (reindeer tracks, restrictions on plantation of lodgepole pine, restrictions on final felling, borders of nature conservations, areas close to mountains and forest stands within Natura2000-areas).

The maps were shown to five of the total nine stakeholders during personal meetings. One representative from the recreation and the representative for the reindeer management had to cancel their meetings due to the storm that made large damages in the forest surrounding Vilhelmina just a week before the meeting. None of the scientist was shown the maps since they did not have any local connection to Vilhelmina. During the meetings discussions were held on the effect different forest management strategies might have on the objective the participants represented; a discussion which got support from the maps. This resulted in an updated zone classification characterised by three different management strategies.

2.2.3 Elicit preference values

The objective of this step is to have the stakeholders judge how important they think different criteria are in a structured way (Nordström, 2010). In this study this was made with the analytic hierarchy process (AHP) which in its full is based on pairwise judgements on the criteria defining the objective and the means (i.e. management plans) to achieve that criteria. In this study the judgments were however only made on the criteria, without any consideration taken to the management plans, in order to counter AHP’s tendency to grow complex as the number of judgements increases. To eliminate the risk of biased judgements each stakeholder assigned weights only to the criteria defining his/her given objective.

The paired comparisons were linked to a numerical and fundamental scale of absolute numbers; see Table 1 (Saaty, 1987). Due to this approach the criteria may take form of both quantitative and qualitative values, making it possible to consider objective information and subjective preferences together; a quality very useful when handling social values. It also made it possible to work with values on different scales (Saaty, 2001). Further details on how AHP is calculated are found in Saaty, 1980.

Table 1. Numerical and fundamental scale of absolute numbers. The judgments on the pairwise comparisons are expressed in terms of the lined up definitions and then assigned a number which can be implemented in AHP. Adapted from Saaty (1987)

Intensity of importance on an absolute scale	Definition
1	Equal importance between two criterion
3	Moderate importance of one criterion over the other
5	Essential or strong importance of one of the criterion
7	Very strong importance of one of the criterion
9	Extreme importance of one of the criterion
2, 4, 6, 8	Intermediate values between the two adjacent judgements. When compromise is needed.

The weights were assigned using Heureka PlanEval. With PlanEval the criteria-weights are automatically normalized to sum to 1 and if more than one stakeholder is involved the weighted arithmetic mean is used to calculate an aggregated set of criteria-weights. The fundamental scale used in PlanEval’s version of AHP lacks the intermediate values rendered in Table 1, but given the advantages gotten in form of automated calculations this was found insignificant for this study.

The weight assignment was conducted during the same meeting as the identification of goals and interest, meaning five people with local attachment to Vilhelmina did it during a personal meeting. Three of these five made the AHP in a group decision, all representing recreation. The representative for the reindeer management was able to elicit the preference values on distance whereas one of the representatives for recreation had to resign from the study due to the heavy workloads that came with the storm. The assignment was also conducted by both scientists at separate personal meetings. All stakeholders, except the representative for the reindeer management who instead filled in a posted paper form, conducted AHP in Heureka PlanEval. To counter the judgements from being biased (a concern mentioned as a threat for a good result by Keeney (1982), the representatives for the interest groups only put weights on the criteria concerning their own objective.

The AHP comparisons are consistent if the given weights (*w*) are $w_{ab}w_{bc} = w_{ac}, \quad \forall a,b,c$, or in other words: if *a* is more important than *b*, and *b* is more important than *c* then *a* must also be more important than *c*. The consistency ratio (CR) is served as a measurement for the consistency. In the study, an inconsistency of 26 % (CR=0.26) was allowed. The recommendation from Saaty (1987) is that the CR should not exceed 0.10, i.e. an inconsistency of 10 %. However, in participatory forestry planning it is not unusual that the CR is allowed to be more than 20 % (e.g. Nordström et al. 2008; Kangas, 1994). In Heureka PlanEval the CR is calculated simultaneously as the weights are set, and some corrections could be made on the judgements given during the meetings.

2.2.4 Generating management plans

The objective of this step is to generate alternative long term forest management plans, which are projections of future treatment proposals and the outcome they bring. The plans should be correlated to the criteria and sub criteria identified (Nordström et al. 2010). This was done by having the management zones created on the basis of the interviews implemented in Heureka PlanWise as three separate forest domains. They were complemented with four extra forest domains which were meant for the stands categorized by some criteria making them of special concern in the simulations. The stands, already defined by the management plan, were sorted into the seven domains according to the descriptions assigned to the domains. Because no stand could be sorted into two domains, even though it matched both descriptions, the domains were ranked and used as a filter. The properties of the stands were compared to each domain's description in falling order, getting sorted in the first one with matching terms (Appendix 2).

Each domain was assigned 1 to 4 control categories, which contained different treatment models, as well as one fixed category rendering ecological consideration at three runs of simulations (the treatment models and the ecological considerations can be seen in Appendix 3). In each simulation up to 100 alternative treatment programs were generated per forest stand using an interest rate of 2 percent and a time horizon of 20 periods, each 5 years long. The optimizer in PlanWise was used to simulate 27 different management plans.

Before the normalization of the values of the criteria, defining the objectives, they needed to be adapted to become easily accessible measures from Heureka PlanWise (and still giving a fair view of the objectives given). This was done using mathematical expressions of the criteria such as "the periodic mean value of the area being clear-cut over the planning horizon. The objective functions used were followed by restrictions in order to prevent the management plans to be oriented extremely towards one objective or a criteria defining an objective. The objective functions and restrictions used can be found in Appendix 4.

2.2.5 Ranking the management plans

The ranking will describe how well the plans are fulfilling the interim objectives (e.g. criteria and sub-criteria) given. With the help of the preference values given to the criteria, the management plans in this study could be ranked using TOPSIS. TOPSIS was used due to its capacity to handle a large number of management plans, and its six steps were implemented in multiple spreadsheets in Microsoft Excel 2010 as follows (for a formal description, see Appendix 5):

1. *Vector normalization.* Since the criteria are measured on different scales they are normalized to 0-1.
2. *Calculation of weighted normalized ratings*. Weights are multiplied with the normalised values from step 1.
3. *Identification of positive-ideal and negative-ideal solutions*. These are expressed as the smallest and largest values of the weighted normalized ratings, respectively, of each criterion.
4. *Calculation of separation measures.* The separation, i.e. the distance, between each normalized value of the given criterion to the positive- and negative-ideal solutions is calculated using the n – dimensional Euclidean distance. The separation is largest between the negative-ideal solution and the positive-ideal solution. All other values are placed in relation to these.
5. *Calculation of similarities to positive-ideal solution.* The separation measure to the negative-ideal solution divided by the sum of the separation measure to the positive-ideal and to the negative-ideal solution. This gives the management plans a value between 0-1 depending on where they place themselves in relation to both ideal solutions.
6. *Ranking of preference order.* The plan rendering the highest similarity to the positive-ideal solution is ranked highest.

The TOPSIS procedure was conducted simultaneously for each interest group, giving a preference order of the management plans per group. By introducing different degrees of importance for each interest group, the management plans were ranked using steps 2-5 and 3-6 in TOPSIS following Wei-guo & Hong (2007) (cited in Krohling & Campanharo (2011), adaption of TOPSIS for participatory planning, Appendix 5). The different weights used can be seen in Table 2. “Production” was first described as the main objective, giving its interest group a weight of 0.5, and the rest of the influence was equally divided between the rest of the interest groups. This allocation of influence was in line with the Swedish law where production, social and ecological values should be equally important (SFS 1979:429). The interest groups where then given equal weights to see how the outcome would be affected if they all had the same influence on the outcome. Finally the “environment” was described as the main objective (due to the result showing that the interim objectives of this interest group were most dissimilar to the other).

Table 2.The weights given to the interest groups at the final ranking of the management plans in TOPSIS

Weight scheme	Production	Environment	Recreation	Reindeer management
Production	0.5	0.5/3	0.5/3	0.5/3
Equal	0.2	0.2	0.2	0.2
Environment	0.5/3	0.5	0.5/3	0.5/3

3 Result

3.1 Stakeholder analysis

A few representatives who could represent the public's opinions were distinguished per interest group. The "production" group was represented by the forest manager for the forest owned by Vilhelmina, the "reindeer management" by a former chairman for a Sami village (Vilhelmina Norra), the "recreation" by four persons with different background and/or recreational interests and the "environment" by the local chairman of a nature conservation association (Naturskyddsföreningen). The interest groups representing "recreation" and "environment" were each complimented with a scientist (both working for the Swedish university of Agricultural science) having expertise in respective interest.

3.2 Identification of goals and interest

3.2.1 Objective hierarchy

The result from the identification of goals and interests is visualised in an objective hierarchy in Fig. 3. No stakeholder wanted any corrections to be made on the first hierarchy created. The overall objective of the forest is decomposed of the four interest groups representing one objective each. Each objective represented by the groups is composed by 3-5 criteria which in 5 cases are composed of 0-3 sub-criteria.

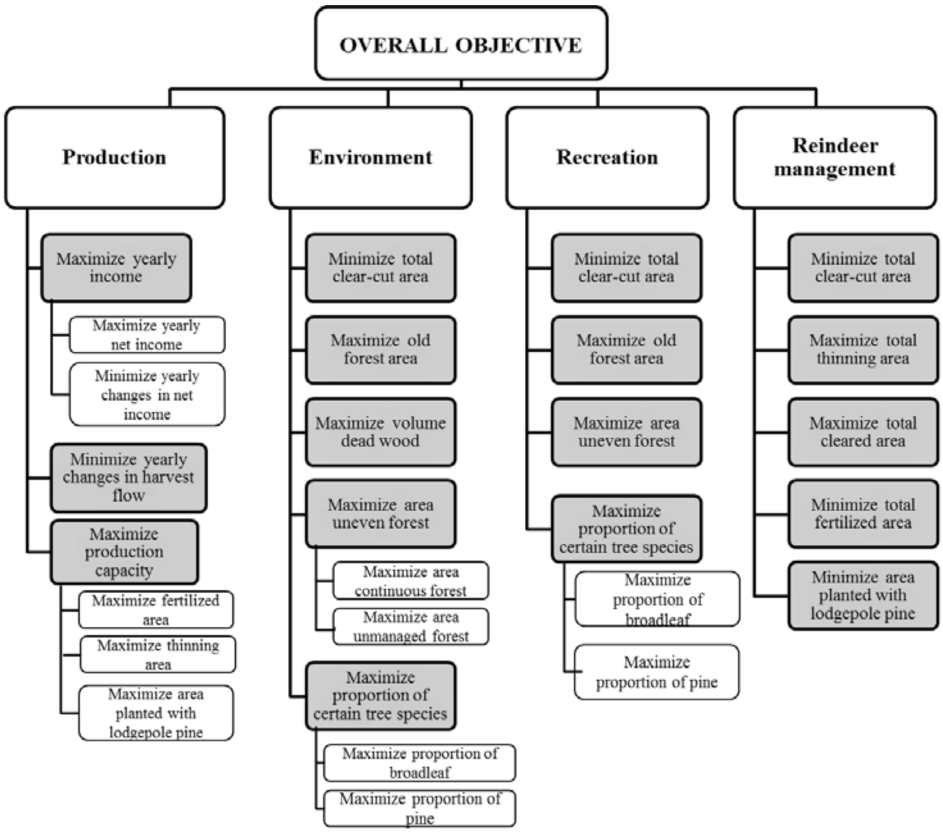

Figure 3. Objective hierarchy. The overall objective is decomposed by the objectives represented by four interest groups: production, environment, recreation and reindeer management, these are in turn decomposed by 3-5 criteria and 0-3 sub criteria.

3.2.2 Zone classification

Having maps rendering the whole forest holdings of Vilhelmina made it possible for the stakeholders to pick out areas of special concern to them, or of which they knew the characteristics of. As result from the discussions concerning the zonal classifications a new zone classification containing three zones were created. These were a zone with prolonged rotation and regeneration under a forest cover, a zone with commercial cutting and a zone with no treatment.

3.3 Elicit preference values

Table 3-11 show the result from the weight assignment which was conducted by the representatives for the interest groups. The CR can be found in Table 3, 5, 6, 9 and 11.

3.3.1 Preference values for the criteria defining the objective "production"

Table 3-5 shows the weights given to the criteria and sub-criteria defining the objective "production".

Table 3. The weights on criteria defining the objective "production", given by one individual (FM). CR = 0.254

Criteria	FM
Max. yearly income	0.45
Min. yearly changes in harvest flow	0.10
Max. production capacity	0.45

Table 4. The weights on the sub criteria to "Max. income", given by the forest manager (FM)

Sub-criteria	FM
Max. yearly net income	0.50
Min. yearly changes in net income	0.50

Table 5 The weights on the sub criteria to "Max. production capacity", given by the forest manager (FM). CR=0.254

Sub-criteria	FM
Max. fertilized area	0.08
Max. thinned area	0.69
Max. area planted with lodgepole pine	0.23

3.3.2 Preference values for the criteria defining the objective "environment"

One representative, environmentalist 1 (E1), had a CR higher than 0.26 and the criteria-weights given by this individual were not aggregated with the result given by environmentalist 2 (E2) (see Table 6-8), neither was it incorporated in TOPSIS.

Table 6. The weights on criteria defining the objective "environment", given by two individuals (E1 and E2). CR = 0.38 for E1 and 0.074 for E2. Due to the high CR of E1 the weights where not aggregated

Criteria	*E1*	E 2
Min. total clear-cut area	*0.29*	0.04
Max. area old forest area	*0.10*	0.09
Max. volume dead wood	*0.46*	0.38
Max. area uneven forest	*0.10*	0.34
Max. proportion of certain tree species	*0.05*	0.15

Table 7. The weights on the sub criteria to "Max. area uneven forest", given by two individuals (E1 and E2)

Sub-criteria	*E1*	E2
Max. area continuous forest	*0.17*	0.10
Max. area unmanaged forest	*0.83*	0.9

Table 8. The weights on the sub criteria to "Max. proportion of certain tree species", given by two individuals (E1 and E2)

Sub criteria	*E1*	E2
Max. proportion of broadleaf	*0.83*	0.83
Max. proportion of pine	*0.17*	0.17

3.3.3 Preference values for the criteria defining the objective "recreation"

The weights to the criteria defining "recreation" was assigned by a single individual, recreationist 1 (R1), and a group of consisting of three individuals, group of recreationist (GoR). Their weight allocations was aggregated using the weighted arithmetic mean, giving an importance of 0.33 to R1 (25 %) and 0.66 to GoR (75 %) (see Table 9-10). Pay attention to that the area uneven forest includes continuous forest cover and forest regenerated under shelterwood (Table 9). These variations were not expressed as sub-criteria when the objective hierarchy was constructed but were used as definitions of an uneven forest when the representatives assigned their weights (they will later return when the ideal solutions for each criterion is defined).

Table 9. The weights on criteria defining the objective "recreation", given by one individual (R1) and a group consisting of three individuals (GoR). CR= 0.246 for R1 resp. 0.253 for GoR. The weighted arithmetic mean was used to get the aggregated result (AGG), CR=0.254

Criteria	R1	GoR	AGG
Min. total clear-cut area	0.13	0.26	0.23
Max. area old forest	0.48	0.12	0.21
Max. area uneven forest*	0.03	0.05	0.05
Max. proportion of a certain tree species	0.36	0.58	0.52

* uneven forest includes continuous forest cover and forest regenerated under shelterwood

Table 10. The weights on the sub criteria to "Max. proportion of certain tree species", given by one individual (R1) and a group consisting of three individuals (GoR)

Sub criteria	R1	GoR	AGG
Max. proportion of broadleaf	0.17	0.17	0.17
Max. proportion of pine	0.83	0.83	0.83

3.3.4 Preference values for the criteria defining the objective "reindeer management"

The result from the weight assignment conducted by the representative for reindeer management can be seen in Table 11.

Table 11. The weights on criteria defining the objective "reindeer management", given by one individual (RM). CR = 0.046

Criteria	RM
Min. total clear-cut-area	0.09
Max. total thinned area	0.06
Max. total cleared area	0.06
Min. total fertilized area	0.38
Min. area planted with lodgepole pine	0.41

3.4 Generating management plans

The mathematical expressions used to operationalize the criteria and sub-criteria are distinguished in Table 12, under "positive-ideal solution in TOPSIS" which also can be read as "maximizations or minimizations of the values given by the operationalized criteria". The criterion "minimize total fertilized area" will work as an example: in Table 12 the positive ideal solution for this is defined as a minimization of the mean value (per period) of the fertilized areas. Appendix 6 shows the values obtained from Heureka PlanWise in order to calculate the operationalized criteria, and the result given by these calculations can be seen in Appendix 7. Some remarks should be made before going on with the rest of the result:

- The area unmanaged forest only gave two values; 610 and 723 ha. This is because they are the outcome of preset values in the ecological control categories, of which there can only be one category per forest domain (for more info see the help site for Heureka PlanWise; Heureka Help).
- The volume dead wood is set to increase over the planning horizon in all management plans, and there are no big differences between the plans.

These variations, or the lack of them, would only affect the interest group representing the objective "environment" since they represented the only objective being decomposed by these criteria.

3.5 Ranking the management plans

3.5.1 Ideal solutions

Table 12 shows the positive ideal solutions which are maximizations or minimizations of the adapted criteria given in Appendix 7. The negative ideal solutions are merely the opposites; e.g. if a positive solution is defined by a maximized criteria; the negative solution is defined by a minimized criteria. Some of the criteria have ideal positive solutions which are defined by two measurements. The weight given to such a criterion or sub criterion will be equally divided between its definitions for positive/negative solutions. Pay attention that the sub-criteria concerning income has increased in number. "Max. the net income the first period" was not a sub-criterion given by the forest manager when identifying the goals and interest for the "Production". It was added while ranking the management plans because of the realization that it was needed in order for there to even be an income the first periods in the highest ranked plans. The weight given to the criterion "max. income" was equally divided between the three sub-criteria, just as it had been when there were only two.

Table 12. Positive ideal solutions for each criterion or sub criterion defined in the objective hierarchy. Each criterion is preceded by a letter describing what objective the criterion is a decomposition of; P=Production, E=Environment, R=Recreation and RM=Reindeer Management. All mean values are per period, one period is 5 years. Some positive ideal solutions are defined by 2-3 measurements with an equal importance.

Criteria as defined in the objective hierarchy	Sub criteria	Positive-ideal solution in TOPSIS
P: Max. Income	Max. yearly net income Min. yearly changes in net income *Max. the net income the first period*	Max. the mean value of the net income Min. the standard deviation between periods of the net income Max. the net income the first period
P: Min. changes in harvesting flow		Min. the percentage changes in harvested areas between periods

P: Max. production capacity	Max. fertilized area Max. thinned area Max. area regenerated with lodgepole pine	Max. the mean value of the areas getting fertilized Max. the mean value of the areas getting thinned Max. the mean value of the areas being regenerated with lodgepole pine
E, R, RM: Min. clear-cut area		Min. the mean value of the clear-cut areas Min. the percentage changes in clear-cut areas between periods
E, R: Max. area old forest per year		Max. the mean value of the volume of forest with a mean age more than 120 years Min. the standard deviation of the volume old forest per period
E: Max. area uneven forest	Continuous forest cover No treatment	Max. the mean value of the areas with continuous forest cover* Max. the mean value of the unmanaged areas
R: Max. area uneven forest		Max. the mean value of the areas with continuous forest cover. Max. the mean value of the areas regenerated under shelterwood
E: Max. volume dead wood		Max. the mean value of the volume dead wood (standing and downed). Min. the standard deviation of the volume dead wood (standing and downed).
E, R: Max. proportion of certain tree species	Max proportion of broadleaf Max. proportion of scots pine	Max. the mean value of the volume broadleaf/scots pine Min. the standard deviation of the volume broadleaf/scots pine
RM: Max. total clearing area		Min. the mean value of areas getting cleared
RM: Min. total fertilized area		Min. the mean value of areas getting fertilized
RM: Min. area planted with lodgepole pine		Min. the mean value of areas getting regenerated with lodgepole pine Min. the standard deviation of the area getting regenerated with lodgepole pine

**Continuous forest in itself was expressed as something negative by the interest group representing recreation but they also express a big liking for a variation in the landscape, with a minimization of clear-cut areas. This rather promoted an existence of continuous forest, which is why it is expressed as maximization.*

3.5.2 Ranking of the management plans per interest group

Table 13 shows the weights given to the four highest ranked management plans per each interest group. No weight has been given to the interest groups themselves and the result given is four individual runs with TOPSIS.

Table 13. The four highest ranked management plans (MP), in falling order, per each interest group.

Production		Environment		Recreation		Reindeer management	
Management plan	Weight	Management plan	Weight	Management plan	Weight	Management plan	Weight
27	0.84	24	0.81	20	0.75	21	0.86
14	0.84	26	0.77	21	0.75	25	0.84
2	0.84	22	0.71	24	0.70	18	0.75
15	0.82	23	0.70	26	0.69	8	0.74

<u>Production</u>

The highest ranked management plan for the interest group “production” was MP27 (see Table 13), MP27 had a maximization of the net income as an objective function, with the restrictions of it being more than 2 million SEK the first period and then not change more than 15 % between the coming periods (see Appendix 4). No management plan got close to reach the economic goal (1 million SEK per year), set by the border of the municipality, during the first period. The restriction given on the change of net income did not reflect on MP27’s yearly changes in harvesting flow (final felling and thinning) which were between 5 – 99 %. According to MP27 a total area of 3248 ha should be fertilized during the planning horizon and 739 ha should be planted with lodgepole pine (these figures are not taking in to account if a forest stand has been planted and/or fertilized more than one time). The mean value of the thinned areas per period should be 263 ha, 102 ha as the lowest and 460 as the highest. All values given can be found in Appendix 6.

<u>Environment</u>

The highest ranked management plan for the interest group “environment” was MP24 (see Table 13). MP24 had a maximization of the net income as an objective function, with no restrictions (see appendix 4). Of all the top four ranked management plan, it was only one (MP22) that had a restriction adapted to the criteria mentioned by the environmentalists, namely a restriction of not letting the clear cut areas exceed 300 ha per period. According to MP24 a total of 1685 ha should be clear-cut the first and second period, the changes in the flow would then be rather low until the two last periods were a total of 2943 ha should be clear-cut. According to MP24 the volume of pine and broadleaf should both increase (213 % resp. 5 %). The volume of old forest (more than 120 years) should decrease (from 2101 m^3sk to 1654 m^3sk). MP24 rendered the second highest amount of land where a continuous forest cover was simulated, 801 ha, and the unmanaged forest should reach 723 ha. All values given can be found in Appendix 6.

<u>Recreation</u>

The highest ranked management plan for the interest group “recreation” was MP20 (see Table 13). MP20 had a maximization of the proportion of pine as an objective function and the restrictions of having a net income more than 2 million SEK the first period, which was not allowed to change more than 15 % between the coming periods, and that the area of old forest should sum up to be more than 800 ha over the periods (Appendix 4). MP20 simulated a relatively small mean value as well as maximum percentage change on the clear cut areas over the planning horizon. With MP20 the total area being clear cut is planned to be evenly spread over the periods, with a decrease in the two last periods (136 ha) compared to the first two (730 ha). According to MP20 the volume of pine and broadleaf will both increase (177 % resp. 1 %). The volume of old forest will decrease, from 2101 m^3sk to 1192 m^3sk. The total area of continuous forest should add up to 470 ha, and forest regenerated under shelterwood should be around 44 ha per period, with the smallest area being 0 ha and the largest being 135 ha. All values given can be found in Appendix 6.

Reindeer management

The highest ranked management plan for the interest group “reindeer management” was MP21 (see Table 13). MP21 had maximization of the volume of scots pine as the objective function and the restrictions of having a net income more than 2 million SEK the first period, which was not allowed to change more than 15 % between the coming periods, and that the area getting fertilized was not allowed to exceed 200 ha per period (Appendix 4). According to MP21 a total area of 2329 ha should be fertilized during the planning horizon and 566 ha should be planted with lodgepole pine (these figures are not taking in to account if a forest stand has been planted and/or fertilized more than one time). The total area being clear cut is planned to be evenly spread over the periods, with a decrease in the two last periods (220 ha) compared to the first two (730 ha). The mean value of the thinned areas per period should be 278 ha, with 116 ha as the lowest and 540 ha as the highest. The mean value of the cleared areas per period should be 225 ha, with 24 ha as the lowest and 431 ha as the highest. All values given can be found in Appendix 6.

3.5.3 Ranking of the management plans with “production” as the main objective

Table 14 shows the ranking of management plans, given by TOPSIS, after a degree of importance has been introduced for each interest group. “Production” is here described as the main objective, giving its interest group a weight of 0.5, and the rest of the influence is equally divided between the other interest groups.

Table 14. The ranking of management plans given by TOPSIS when a degree of importance has been introduced for each interest group (0.5 to “production” and 0.5 divided equally between the other interest groups)

Rank	Management plan	Weight
1	21	0.86
2	20	0.84
3	27	0.83
4	25	0.82

Table 15 shows that “production”, “recreation” and “reindeer management” all ranked the highest ranked management plan in Table 14 rather high individually, while quite the opposite remark can be made with the “environment” which ranked it in the bottom ten.

Table 15. How each interest group ranks the management plans rendered in Table 17

	Production		Environment		Recreation		Reindeer management	
Managament plan	Rank	Weight	Rank	Weight	Rank	Weight	Rank	Weight
21	7	0.80	22	0.56	2	0.75	1	0.86
20	4	0.82	20	0.57	1	0.75	6	0.73
27	1	0.84	11	0.64	15	0.59	9	0.66
25	13	0.77	13	0.63	17	0.58	2	0.84

Some of the outcome from the treatment suggestion set by MP21 has already been shown under "*3.5.2 Ranking of the management plans per interest group*" where MP21 was ranked highest for the interest group "reindeer management". In order to capture its influence on the other objectives some additional remarks will follow: With MP21 the volume old forest should decrease from 2101 m^3sk to 1042 m^3sk. The volume of pine and broadleaf should both increase (186 resp. 2.5 %). MP21 rendered the smallest amount of land where a continuous forest cover was simulated, 294 ha, and a relatively high mean value of forest being regenerated under shelterwood; 51 ha, with the smallest area being 0 ha and the largest area being 139 ha. The volume dead wood should be about 9 m^3sk per hectare, with a standard deviation of 5 m^3sk per hectare. Both MP20 and MP21 (the two highest ranked management plans in Table 17) had been assigned an ecological control category rendering the smallest area of unmanaged forest, 610 ha. All values given can be found in Appendix 6.

3.5.4 Ranking of the management plans with all objectives equally taken in consideration

Table 16 shows the ranking of management plans, given by TOPSIS, when an equal degree of importance has been assigned to each interest group.

Table 16. The ranking of management plans given by TOPSIS when an equal degree of importance has been introduced for each interest group (0.2 each)

Rank	Management plan	Weight
1	21	0.78
2	25	0.77
3	20	0.77
4	27	0.72

Just as when "production" was described as the main interest, Table 17 shows that production, "recreation" and "reindeer management" all ranked the highest ranked management plan in Table 16 rather high individually, while quite the opposite remark again can be made with the "environment" which ranked it in the bottom ten.

Table 17. How each interest group ranks the management plans rendered in Table 19

	Production		**Environment**		**Recreation**		**Reindeer management**	
Managementt plan	Rank	Weight	Rank	Weight	Rank	Weight	Rank	Weight
21	7	0.81	22	0.56	2	0.75	1	0.86
25	13	0.77	13	0.63	17	0.58	2	0.84
20	6	0.81	20	0.57	1	0.75	6	0.73
27	1	0.84	11	0.64	15	0.59	9	0.66

3.5.5 Ranking of the management plans with "environment" as the main objective

Table 18 shows the ranking of management plans, given by TOPSIS, after a degree of importance has been introduced for each interest group. "Environment" is here described as the main objective, giving its interest group a weight of 0.5, and the rest of the influence is equally divided between the other interest groups.

Table 18. The ranking of management plans given by TOPSIS when a degree of importance has been introduced for each interest group (0.5 to "environment" and 0.5 divided equally between the other interest groups)

Rank	Management plan	Weight
1	26	0.75
2	27	0.65
3	25	0.64
4	15	0.63

Table 19 shows that only "recreation" ranked the highest ranked management plan in Table 18 rather high.

Table 19. How each interest group ranks the management plans rendered in Table 20

	Production		**Environment**		**Recreation**		**Reindeer management**	
Managament plan	Rank	Weight	Rank	Weight	Rank	Weight	Rank	Weight
26	18	0.50	2	0.77	4	0.69	10	0.64
27	1	0.84	11	0.64	15	0.59	9	0.66
25	13	0.77	13	0.63	17	0.58	2	0.84
15	4	0.81	16	0.62	19	0.57	8	0.67

MP26 had a maximization of the net income as objective function, with a restriction that the area getting fertilized per period could not exceed 100 ha (see Appendix 4). The volume old forest should decrease from 2101 m^{3}sk to 1708 m^{3}sk, and the volume of pine and broadleaf should increase (109 resp. 2 %). MP26 rendered the second biggest amount of land where a continuous forest cover was simulated, 856 ha, and a relatively low mean value of forest being regenerated under shelterwood; 36 ha, with the smallest area being 0 ha and the largest being 192 ha. The volume dead wood should be about 10 m^{3}sk per hectare with a standard deviation of 7 m^{3}sk per hectare. MP26 was assigned the ecological program rendering the biggest area of unmanaged forest, 722 ha. A total area of 1669 ha should be fertilized during the planning horizon and 619 ha should be planted with lodgepole pine. The total area being clear cut is planned to be 1609 ha the first period, followed by relatively low variations until the last period when 2444 ha is being clear cut. The mean value of the thinned areas per period should be 243 ha, with 1 ha as the lowest and 682 ha as the highest. The mean value of the cleared areas per period should be 158 ha, with 5 ha as the lowest and 826 ha as the highest. All values given can be found in Appendix 6.

4 Discussion

This study illustrates an approach for ranking long term forest management plans with consideration to multiple objectives by combining AHP with TOPSIS. The discussion will first consider the methodological pro and cons of the approach, then deal with properties of the case study as such, and conclude with some thoughts about future research.

4.1 Reliability of the case study data

The result from this study showed that it is possible to evaluate the outcome of a high number of management plans, and rank them according to how suitable they were for a given objective, and still keeping the process easily structured and understandable. The result also showed that the ranking could be adapted to handle multiple objectives, defined by multiple criteria. These statements derive from the results given by the combination of AHP with TOPSIS, where TOPSIS was used to compare and rank 27 management plans with the results gotten from interviews were the criteria defining a given objective had been discussed and given weights with AHP.

During the criteria weight assignment the participants were encouraged to ask questions surrounding the criteria, the sub criteria and the AHP itself; which lessened the chance for misconceptions and encouraged a deeper knowledge in how their judgments would affect the objectives they represented. Allowing the representatives to ask questions about the AHP and changing their own answers probably made them feel more confident with the situation, which according to Keeney (1982) has a positive impact on the result.

By using the same approach as Wei-guo & Hong (2007) (cited in Krohling & Campanharo (2011) TOPSIS was adapted to a decision process involving several of stakeholders. No difficulties concerning this particularly approach was met and the strengths of TOPSIS could fully come forward; by implementing TOPSIS in the decision process the representatives did not need to make judgments on the management plans' importance for the fulfilment of the given objective. This simplification of the weighting process makes it adapted to people without a good understanding in how different forest management strategies might affect their objective, which might increase the will to participate among the public. It should also increase the will among people without a special interest in the outcome to participate, an assumption finding support in Kangas' (1994) findings that only the stakeholders with a special interest in the outcome were willing to make judgments on the plans' relative importance. The withdrawal of the management plans from AHP also entirely dismisses the otherwise necessary subjective selection of plans, which was expressed as a weakness by e.g. Nordström et al. 2008.

An advantage with TOPSIS, like with other weighting methods, was that it was clear to see how the adaptation to one objective influenced the fulfillment of another objective by evaluating the outcome from putting different weights on the influence given by the interest groups. The outcome was also easy to track back in the process, for example it was clear that it was crucial for an objective to share some its criteria with another objective in order to get a suitable management plan ranked high. When ranking the management plans, MP21 and MP26 came out as the highest ranked plans. MP21 had been assigned an ecological control category rendering not only the smallest area of unmanaged forest but also the smallest amount of land where a continuous forest cover was simulated; two criterions ranked high only by the interest group “environment”, which had to be expressed as the main objective for these interim objectives to be fulfilled. “Recreation” on the other hand, shared two of its highest ranked criteria with two other objectives which brought an increased chance that the plan ranked highest would be more suitable for the objective “recreation” than other equally weighted objectives.

Even if the results from the case study seem to be promising they raise some issues that need to be discussed on how different criteria should be expressed. One issue concerns how to deal with unrealistic targets. For instance, the result showed that it was not always so that the management plan ranked highest for the objective of an interest group actually could be considered being in line with the given goals and interests. For example: the highest ranked management plan for the interest group representing “production” was MP27. With MP27 the economic goal, 1 million SEK, set by the border of Vilhelmina will not be reached during the first ten periods. However, none of the plans reached a net income that high during the first three periods, and those bringing a net income over 1 million SEK per year as early as in the third period did not render any income at all in the first two periods. Since the ranking is based on relative values, the highest ranked management plan is to be considered as the most suitable among all plans present rather than the perfect solution. That the goal of 1 million SEK per year was not reached indicates therefore that the creating of management plans need rethinking.

Further, it is important to remember that some of the ideal solutions were expressed only in terms of mean values of the total outcome, e.g. the mean value of the total area being thinned under the whole planning horizon. A mean value like this does not say anything on how the value is changing over time (meaning that there can be big fluctuations and/or the area can decrease over time and still render a relatively high mean value). Although this did not seemingly affect the interim objectives given by the interest groups representing “production” or “reindeer management” (which were the only groups having ideal solutions expressed only as mean values), big fluctuations are probably not something any of them see as a suitable fulfilment of their given objective.

There were also ideal solutions expressed as mean values combined with another mathematical expression. The ideal solution explaining the presence of dead wood, old forest, pine trees, broadleaf and lodgepole pine are examples of solutions which were expressed as a mean values and standard deviations (based on periods). The intention of using the standard deviation was to counter possible fluctuations, but it proved to be an excess. The volume of dead wood as well as the volume of pine trees and broadleaf were all constrained to increase in all management plans, without any big fluctuations, and therefore the ideal solution could have been simplified to only handle the mean value (since there was no excluded wish in how fast the volume should grow). The volume of old forest did however show a decrease in all management plans[6], which also held rather similar fluctuations, indicating the constraints given were not sufficient with meeting the goals and interest given by the interest groups “environment” and “recreation”.

The ideal solutions explaining clear-cut area and net income are examples of solutions expressed as mean values combined with the percentage change over periods. The interim objective of minimizing the clear-cut area was met with similar difficulties as the interim

[6]The constraint associated with this criterion was set as a lower bound and not as an increase, see Appendix 4.

objectives expressed only as mean values, where a plan might simulate a slight increase of areas being clear-cut over the planning horizon and by that render a relative small percentage change over the periods, increasing its rank. Such a plan will also promote a relatively high mean value which will slightly lower its rank. The outcome from this is however that there is a chance that such a plan will be higher ranked than the intention of the interest groups, which for example was the case for the group “environment” whose highest ranked management plan actually simulated an increase of areas being clear-cut (which hardly can be seen as a fulfilment of the given interim objective). The interim objective of maximizing the net income did not meet the same difficulties since the net income was increasing in all management plans created.

4.2 Reliability of the case study data

Finally, even if the suggested approach of combining AHP with TOPSIS seems to be ready for implementation a few limitations in the case study have to be mentioned. First, the composition of this study was made according to the given time frames, namely 20 weeks. Because of this the interviews made had to be short and limited to one personal meeting. Nor were there time for any interactions between the interest groups. To keep the number of interviews down might have affected the data; it is a general opinion among interviewers that several of interviews provide better data than if only one is conducted (Starrin & Renck, 1996). With no interactions the representatives were not given the opportunity to increase their awareness and understanding for each other, which often is mentioned as one of the most positive contribution participatory planning processes bring. However, having the public’s opinion heard through their representatives has, according to (Khadka et al. 2013), the same ability as interactions to build a higher commitment among local stakeholders.

Second, when conducting the AHP, an inconsistency (CR) of 26 % was set as the upper border. This might seem as a big step from the, by Saaty (1987) recommended 10 %. However, in participatory forestry planning it is not unusual that the CR is allowed to be more than 20 %, partly due to its inclusion of people without a deep knowledge in forestry and partly because the calculations of the CR have not been run in connection with the judgments have been made (e.g. Nordström et al. 2008; Kangas, 1994). Even though the CR was available directly after the judgments were made in this study, the representatives were only asked to rethink the judgments with the most obvious inconsistencies. To demand them to rethink all of their judgments was thought to impose a risk of them beginning to mistrust the method, and thereby the result.

Third, in this study no discussion was held with the border of the municipality in how the weights should be allocated between the interest groups. The purpose of MCDA it to help decision makers make better decisions. It is not to provide with an absolute answer on what decision should be made (Keeney, 1984). Reasoning this way it seems unnecessary to have absolute weights given to the interest groups. By changing the weights between the interest groups one might instead see what impact the fulfillment of an objective have on the fulfilment of other objectives.

Fourth, the values given from the result are stretching over the whole forest owned by the municipality of Vilhelmina and do not pay attention to place-specific areas: meaning there is no good way to know where an increase of e.g. pine trees might happen. Since different areas are of special concern for different interest groups it might be more meaningful to have their interest weigh more in those areas than in others.

4.3 Future research

Much of the final ranking of the management plans was based on how the ideal solutions were defined, and then especially how they managed to handle the complexity of dimensional values (e.g. the dynamic change of old forest over the planning horizon or the spatial relations of old forest areas). When the ideal solution was deficient in capturing this complexity the highest ranked plan could be somewhat unsuitable for the given objective (e.g. "environment"). Korosuo et al. (2013) acknowledged the difficulty of dimensional values and tested, with promising result, using value functions in order to define them. No MCDA process was however conducted in their study and it would be interesting for future research to see if there is an applicability of incorporating value functions into a MCDA process concerning forest management planning.

All spatial considerations taken in this study was made using an exogenous approach by dividing the forest into different management zones. To start with it would be possible to, still using the exogenous approach, create management plans with different allocation of zones and by that render a more diverse data set. This would however also be a very time consuming task and therefore it might be more advantageous to go by an endogenous approach (e.g. by using value functions), and by that use the full potential of TOPSIS as a decision support tool.

It should also be possible to, on basis on the already generated and ranked plans generate a management plan that is fulfilling multiple objectives better than the ones already generated. To leave out the management plans from the weighting process does not only makes it possible to evaluate the influence different treatments have, it is also possible to complemented the ranking process with extra plans without having to redo any step in the process other than extending the TOPSIS-formula in Excel. This might be found very helpful for the decision maker who is responsible to come up with a management plan adapted to multiple objectives and therefore an interesting question for feature research.

4.4 Conclusion

The result from this study showed that there is an applicability of combining TOPSIS and AHP for including consideration to multi objectives into strategic forest management planning. By dismissing the selection of a few plans the full capacity of Heureka PlanWise's ability to create numerous of management plans can come forward, which in turn reduced the chance that the optimal plan is missed. The combination of AHP with TOPSIS makes it easy for the decision maker to understand how adaptations to different objectives affect each other.

TOPSIS also offers a method that makes it easy to implement into a participatory forestry planning. The participants understood the concepts on which the methods were based and could, even without good knowledge in forestry, get their opinions heard and taken accounted for.

I hope that the concept presented here for ranking forest management plans, will contribute to the available tools for including consideration to multiple objectives and the involvement of different stakeholders in long term forest management planning.

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Appendix 1

Interview guide for the representatives for the objectives:"environment", "recreation" and "reindeer management"
Date: ________
Name: _________________________

Represents the objective:
Environment Recreation Reindeer management

1) In what way do you represent your objective?
2) How do the people having interest in your represented objective use the forest areas around Vilhelmina?
3) Are there any special forest areas these people might prefer?
   a) Can you describe these areas, how are they used?
   b) What is good with the area, what is missing?
   c) How would you like these areas to be managed?
4) How would an ideal forest area look like in order to fulfill the objective you represent?
5) In what way do silvicultural treatments affect your objective?
6) Would you like to expand have other forest areas than the ones already used to be more adapted to your objective?
   a) What would have to be done, in terms of forest treatments, in order to have these forest areas to be suitable your objective?
7) What is your thought on of how the forest is managed today, based on the objective you represent?

Length of interview _______________

Interview guide for production
Date: ________
Name: _________________________

1) In what way do you represent your objective?
2) What does the border of Vilhelmina demand from the forest in terms of production values?
3) What is needed from different silvicultural methods (regeneration, thinning, scarification, fertilization) in order to optimize the given objective
4) What is your thoughts on how the forest is managed today, based on the objective you represent?
   a) What is your opinion of what can be improved?

Length of interview _______________

Appendix 2

The stands, already defined by the management plan, were sorted into the seven domains according to the descriptions given in Table 20. The properties of the stands were compared to each domain's description in falling order, getting sorted in the first one with matching terms. Table 21 shows the distribution of the total area of the stands per forest domain.

Table 20. The seven forest domains implemented in Heureka PlanWise. They are ranked in order to function as a filter for the forest stands being sorted into them. The zones created on basis of the second turn of interviews is written in bold letters

Forest domain	Rank	Description
Zone No Treatment	1	Stands with management class NO (no treatment).
No Final Felling	2	One stand within the borders where no final felling
Broadleaf	3	Stands with broadleaf as the dominant tree species
PF	4	Stands with management class PF (CC with enhanced consideration)
Zone No Commercial Cutting	5	Stands close to or within Vilhelmina, hiking trails, reindeer trails, nature conservations and recreation areas
No lodgepole pine	6	Inside the border where lodgepole pine is not allowed to be planted
Zone Commercial Cutting	7	All other stands not defined in the above mentioned

Table 21. The total area (ha) of the forest stands getting sorted under every forest domain. The zones created on basis of the second turn of interviews is written in bold letters

Zone no treatment	No final felling	Broadleaf	PF	**Zone no commercial cutting**	No lodgepole pine	**Zone commercial cutting**
329	6	332	16	760	3449	1046

Table 22 shows the treatment programs as well as the ecological programs assigned to the seven forest domains, a more comprehensive description of the programs can be found in Appendix 2.

Table 22. The treatment programs and the ecological programs assigned to the forest domains at three runs of simulations. The zones created on basis of the second turn of interviews is written in bold letters

Forest domain	Simulation 1	Simulation 2	Simulation 3
Zone No Treatment	No management	No management	No management
No Final Felling	No final felling *Commercial cutting set aside*	No final felling *Commercial cutting set aside*	No final felling *Commercial cutting set aside*
Broadleaf	Broadleaf management No final felling *Commercial cutting set aside*	Broadleaf management No final felling Commercial cutting 1 Commercial cutting 2 *Commercial cutting set aside*	Broadleaf management No final felling Commercial cutting 1 Commercial cutting 2 *Commercial cutting set aside*
PF	No lodgepole pine or fertilizer *Extra set aside*	No lodgepole pine or fertilizer *Extra set aside*	No lodgepole pine or fertilizer *Extra set aside*
Zone No commercial cutting	Keep overstorey 2 No final felling *Extra set aside*	Keep overstorey Keep overstorey 2 No final felling *Commercial cutting set aside*	Keep overstorey Keep overstorey 2 No final felling *Commercial cutting set aside*
No lodgepole pine	No lodgepole pine *Commercial cutting set aside*	No lodgepole pine No lodgepole pine or fertilizer *Commercial cutting set aside*	No lodgepole pine No lodgepole pine or fertilizer *Commercial cutting set aside*
Zone Commercial cutting	Commercial cutting 1 *Commercial cutting set aside*	Commercial cutting 1 Commercial cutting 2 *Commercial cutting set aside*	Commercial cutting 1 Commercial cutting 2 No lodgepole pine No lodgepole pine or fertilizer *Commercial cutting set aside*

Appendix 3

Treatment models and <u>ecological considerations</u>:

Commercial cutting 1
Regeneration: Lodgepole pine (*Pinus contorta*) is planted or sown under shelterwood in stands characterized by the vegetation types blueberry, lingonberry or shrubs and a site index less than T23. Scots pine trees (*Pinus sylvestris*) are sown under shelterwood in stands characterized by the vegetation types lingonberry, shrubs or lichen and a site index less than T26. When none of the above conditions are met the stand will be final felled and planted with a species (scots pine or Norwegian spruce, *Picea abies*) suitable for the given site index.
Clearing: The clearing is set on keeping the main stems in the stand. The cost for the clearing is set on a fixed price of 1700 SEK per hectare.
Thinning: Every stand will be thinned 1-3 times depending on its characters. The thinning grade is set to 20 – 40 % and the minimum time between two thinning is set to 5 years.
Fertilization: The land is fertilized every thinning.
Logging residuals: Logging residuals are extracted at final felling.

Commercial cutting 2
The land is fertilized once before the last thinning and once before the final felling. All other treatment settings are the same as in “Commercial cutting 1”.

No lodgepole pine or fertilizer
The stand will be final felled 0 – 30 years after the lowest allowable felling age has been reached.
Regeneration: Scots pine trees (*Pinus sylvestris*) are sown under shelterwood in stands characterized by the vegetation types mulberry, shrubs or lichen and a site index less than T26. When none of the above conditions are met the stand will be final felled and planted with a species (scots pine or Norwegian spruce, *Picea abies*) suitable for the given site index.
Clearing and thinning: Same as “Commercial cutting 1”
Fertilization: No fertilization.
Logging residuals: Same as “Commercial cutting 1”

Keep overstorey 1
Regeneration: The lowest allowable felling age is delayed with 30 %. The stand will be final felled 20 – 30 years after the lowest allowable felling age has been reached. Species suitable for the given site index (scots pine or Norweigan spruce) are planted under a shelter wood.
Clearing and thinning: Same as “Commercial cutting 1”
Fertilization: No fertilization
Logging residuals: Same as *“Commercial cutting 1”*

Keep overstorey 2
No logging residuals are extracted, all other treatment settings are the same as in “Keep overstorey 1”.

No lodgepole pine
Regeneration: Scots pine trees (*Pinus sylvestris*) are sown under shelterwood in stands characterized by the vegetation types mulberry, shrubs or lichen and a site index less than T26. When none of the mentioned suggestions are in line with the given goal the stand will be final felled and planted with a species (scots pine or Norwegian spruce) suitable for the given site index.
All other treatment settings are according to those of “Commercial cutting 1”.

Broadleaf management
Regeneration: The regenerating will be under seed trees.
Clearing: Same as Commercial cutting 1
Thinning: The dominant species is favored.
Fertilization and logging residuals: Same as “Commercial cutting 1”

No final felling
Thinning: The thinning grade is set to 20 – 35 % and the minimum time between two thinning is set to 10 years.
Fertilization: no fertilization

No treatment
No treatment methods are applied

<u>*Conventional logging, set aside*</u>
5 % is set aside to remain undisturbed of treatments. 10 trees per hectare are saved for conservation interests.

<u>*Extra set aside*</u>
10 % is set aside to remain undisturbed of treatments. 10 trees per hectare are saved for conservation interests.

Appendix 4

Table 23 shows the objective functions and restrictions set when generating the 27 management plans, at three different runs of simulations.

Table 23. The objective functions (bold letters) and the restrictions assigned to the 27 management plans, at three run of simulations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Simulation	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3
Highest net present value	X						X																X				
Highest net income		X	X					X	X	X	X													X	X	X	X
Largest volume dead wood				X	X	X						X	X	X	X	X						X					
Increase volume scots pine																	X	X	X	X							
Minimum of a net income of 2 million SEK the first period								X		X			X	X	X			X		X	X						X
Minimum of a net income of 1.5 million SEK the first period		X		X		X																					
Maximum change of 10 % of the net income over periods								X		X			X					X							X		
Maximum change of 15 % of the net income over periods		X		X	X	X								X	X					X							X
More than 800 ha old forest in every period					X	X					X	X		X					X	X							
Increase volume scots pine from a period to another					X	X																					
Increase volume broadleaf from a period to another					X	X																					
Fertilized areas smaller than 200 ha/period										X					X						X				X		
Clear-cut areas smaller than 300 ha/period			X						X													X					
Fertilized area less than 100 ha/period																									X	X	

Appendix 5

The six steps of TOPSIS (Hwang & Yoon, 1995):

Step 1: Vector normalization

$$r_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^{2}}}, \qquad i=1, \ldots, n; j=1, \ldots, m$$

where x_{ij} is the value of the *i*th criterion assigned to the *j*th alternative.

Step 2: Calculate weighted normalized ratings

$$v_{ij}=w_j r_{ij}, \qquad i=1, \ldots, n;\ j=1, \ldots, m$$

where w_j is the given[7] weight for r_{ij}.

Step 3: Identify positive-ideal and negative-ideal solutions where A^* gives the positive-ideal solution and A^- the negative-ideal solution,

$$A^*=\{v_1^*, v_2^*, \ldots, v_j^*, \ldots, v_m^*\}$$

$$=\left\{\left(\max_i v_{ij} / j \in J_1\right), \left(\min_i v_{ij} / j \in J_2\right) / i=1, \ldots, n\right\}$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_j^-, \ldots, v_m^-\}$$

$$=\left\{\left(\min_i v_{ij} / j \in J_1\right), \left(\max_i v_{ij} / j \in J_2\right) / i=1, \ldots, n\right\}$$

where J_1 is a set of benefit criteria and J_2 a set of cost criteria.

Step 4: Calculate separation measures. The separation (distance) between alternatives can be measured by the n – dimensional Euclidean distance. The separation of each alternative from the positive-ideal solution, S_i^* , and likewise from the negative-ideal solution, S_i^-, is given by

$$S_i^*= \sqrt{\sum_{j=1}^{m}\left(v_{ij}-v_j^*\right)^2}, \quad i=1, \ldots, n$$

$$S_i^- = \sqrt{\sum_{j=1}^{m}\left(v_{ij}-v_j^-\right)^2}, \quad i=1, \ldots, n$$

Step 5: Calculate similarities to positive-ideal solution.

$$C_i^*= S_i^- \Big/ \left(S_i^*+S_i^-\right), \qquad i=1, \ldots, n,$$

Step 6: Rank preference order. The alternative rendering the highest similarity to the positive-ideal solution, C_i^*, is ranked highest and followed by the other alternatives in descending order according to their C_i^*.

[7] TOPSIS is not providing weight elicitation and the weight is either a subjective estimation or obtained from mathematically from another MCDA.

TOPSIS in participatory planning according to Wei-guo & Hong (2007), cited in Krohling & Campanharo (2011):

A group consists of L members who participate in the decision making-process. This is given by

$$G=\{M_1, M_2, \ldots, M_L\}.$$

The weights of criteria for each group member are described by

$$W^l=\left(w_1^l, w_2^l, \ldots, w_n^l\right), \quad l=1, \ldots, L$$

$$0 \leq w_i^l \leq 1, \quad \sum_{j=1}^{n} w_i^l = 1,$$

where w_i^l represents the weight assigned to criteria C_i by the group member M_l.
Each group member has a degree of importance described by

$$0 \leq \alpha_l \leq 1, \quad \sum_{i=1}^{n} \alpha_l = 1.$$

The next steps are following that step 2 to 5 of the original TOPSIS, calculating the similarities to positive-ideal solution simultaneously for each group member. The result will give a relative closeness for each alternative A_i of each member l, ending in a relative-closeness matrix

$$\text{RCM} = \begin{pmatrix} \aleph^l(A_1) & \cdots & \aleph^L(A_1) \\ \vdots & \ddots & \vdots \\ \aleph^l(A_m) & \cdots & \aleph^L(A_m) \end{pmatrix}.$$

By introducing the importance weights of the group members into the relative-closeness matrix we are back at step 3 in the original TOPSIS which can be followed all the way to its final step; "*Step 6: Rank Preference Order*".

Appendix 6

Table 24 – 36 shows the values given by the adapted criteria. The values for the area unmanaged resp. continuous forest were both constant over the planning horizon and can be seen in Table 24. The bold letters and numbers in each table describe the adapted criteria, which would be used to render out the positive- and negative-ideal solutions of TOPSIS.

Contents of Table 25-36:
Table 25: total area being planted with lodgepole pine per period
Table 26: the periodic change of harvested volumes
Table 27: the total area getting thinned per period
Table 28: the total area getting cleared per period
Table 29: the total area getting clear-cut per period
Table 30: the total area getting fertilized per period
Table 31: the total volume of old forest per period
Table 32: the total area of forest being regenerated under shelterwood per period
Table 33: the total volume of scots pine per period
Table 34: the total volume of broadleaf per period
Table 35: the net income per period
Table 36: the total volume of dead wood per period
In some tables period 0 is marking the initial state of the forest holdings.

Table 24. The area (ha) of forest being continuous or unmanaged per management plan

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Continuous	**329**	**329**	**329**	**329**	**644**	**476**	**801**	**521**	**942**	**441**	**811**	**619**	**429**	**616**	**609**	**619**	**324**	**352**	**506**	**470**	**294**	**619**	**791**	**801**	**542**	**855**	**552**
Unmanaged	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**610**	**723**	**723**	**723**	**723**	**723**

Table 25. Area (ha) planted with lodgepole pine per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values and the standard deviations (S.D.) are per period. The total area being planted with lodgepole pine is also given.

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0	0	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
1	2,5	3	32		37	45	39	3	37		37		2	37	39	39	2		35		15	15	5	3		28		34
2	7,5	13	13	55	24	52	31		11	54	12			12	12	12			13		18	18	1			10		12
3	12,5	5	26	7	15		8	21	44	11	32			43	36	40			39		19	19	63	20		30		32
4	17,5	4	25	4	21		19	2	9	4	26			10	10	5			10		21	21	14	2		22		20
5	22,5	1	7	15	10		10		13	4	8			5	10	10			10				4			7		8
6	27,5		14		13		13		16	7	16			14	15	15			14				4			18		16
7	32,5	73	12	19		2		93	10	19	11	119	97	24	22	9	97	99	8	99	25	31	9	91	117	34	117	27
8	37,5	1	9		13		13	1	30		29			29	7	7			30		15	9		1		3		11
9	42,5	9	76	3	2	3	29	10	53	3	55	4	3	55	27	29	3	3	51	3	30	30	3	10	4	78	4	71
10	47,5	37	16		38	16	6	36	32		30	4		30	8	6			37		4	4		35	4	33	9	24
11	52,5	22	52	5	45	62	54	24	39	5	61	5	7	52	29	40	7	5	36	5	35	35	9	23	5	51	5	35
12	57,5	39	49	14	42	25	44	45	21	15	42	12	15	52	26	26	15	14	22	14	26	26	23	44	12	20	8	29
13	62,5	33	24	11	22	21	22	28	36	11	31	9	11	42	21	21	11	11	30	11	16	16	11	28	9	13	8	40
14	67,5	94	27	129	93	84	55	86	44	128	61	28	28	64	120	110	28	28	19	28	58	58	37	84	27	28	27	43
15	72,5	60	56	53	57	55	48	72	44	52	47	64	64	8	34	47	64	64	40	64	37	37	117	70	63	69	63	76
16	77,5	29	54	62	28	28	43	25	30	65	30	23	23	38	28	28	23	23	11	23	8	8	39	24	22	61	22	58
17	82,5	33	36	26	17	40	16	32	68	28	23	52	36	18	27	22	36	35	42	35	41	41	37	31	51	20	51	16
18	87,5	22	64	84	25	21	25	20	19	82	20	61	59	17	45	45	59	61	44	61	50	50	58	19	60	44	60	65
19	92,5	10	32	58	29	29	29	15	28	58	24	132	54	21	29	23	54	46	41	46	47	47	45	15	129	67	129	42
20	97,5	2	62		36	79	64		24		30	99	87	20	36	32	87	95	51	95	83	83	79		97	34	102	64
Mean value		**24**	**33**	**27**	**28**	**28**	**28**	**25**	**30**	**27**	**31**	**30**	**24**	**29**	**28**	**28**	**24**	**24**	**28**	**24**	**27**	**27**	**27**	**25**	**29**	**33**	**29**	**35**
	S.D.	**26**	**21**	**36**	**20**	**25**	**17**	**28**	**16**	**35**	**15**	**44**	**31**	**17**	**24**	**23**	**31**	**33**	**15**	**33**	**19**	**20**	**31**	**27**	**43**	**21**	**44**	**21**
Total area		506	701	560	584	579	584	527	624	561	641	627	500	608	598	585	500	499	598	499	566	566	573	516	614	685	619	739

Table 26. The periodic change (%) of harvesting values given per management plan. One period is 5 years and the values are given in the middle of each period. The maximal periodic change over the planning horizon is also given. No volume were harvested in period 0 and therefore the first periodic change displayed is between period 1 and 2

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
2	7,5	8	37	76	9	92	8	38	31	71	33	98	100	34	21	19	100	91	29	91	1	0	98	38	98	35	99	27
3	12,5	318	4	7	9	37	9	1001	33	14	33	90	100	26	9	14	100	50	33	64	22	25	82	1001	90	52	22	29
4	17,5	5	10	164	1	14	31	23	7	174	3	20	100	5	6	5	100	26	3	36	6	0	4	23	20	11	57	10
5	22,5	5	43	1	58	9	24	0	52	3	60	100	100	64	69	71	100	129	55	12	44	54	2	0	0	45	100	58
6	27,5	17	1	1	8	31	2	27	5	5	32	100	100	32	37	26	100	74	34	54	36	36	1	27	0	11	100	13
7	32,5	259	133	8	281	11	48	252	45	3	15	177	1924	29	103	160	1924	134	16	229	34	16	72	252	172	130	193	99
8	37,5	91	70	78	81	70	71	91	65	76	65	60	93	67	68	67	93	74	77	84	79	78	76	91	60	60	64	67
9	42,5	23	20	20	31	32	8	24	35	25	30	19	51	22	39	56	51	40	17	108	34	29	51	24	19	47	19	29
10	47,5	45	4	23	48	13	24	38	127	23	118	18	43	104	37	97	43	64	196	55	40	100	43	38	18	48	9	60
11	52,5	20	15	56	22	52	65	4	21	56	34	59	72	28	19	11	72	163	27	56	50	77	68	4	59	32	63	14
12	57,5	74	20	302	16	36	20	23	22	308	39	106	229	32	26	2	229	9	12	21	13	19	223	23	106	47	85	9
13	62,5	43	49	70	101	26	69	54	102	70	74	45	69	108	99	133	69	242	84	242	66	60	71	54	45	48	42	5
14	67,5	74	8	813	5	29	0	78	53	762	136	135	103	56	2	4	103	49	42	49	115	123	134	78	135	2	148	21
15	72,5	13	20	47	33	38	38	8	74	60	76	95	203	78	47	43	203	72	73	73	69	70	244	8	95	15	95	37
16	77,5	20	41	22	41	64	82	30	11	17	10	77	14	61	18	8	14	16	11	20	41	50	7	30	77	39	77	24
17	82,5	34	6	10	42	31	47	29	23	6	54	15	19	43	46	13	19	34	18	34	18	32	75	29	15	8	15	16
18	87,5	8	42	3	56	5	24	7	23	5	63	10	17	6	37	38	17	98	4	94	26	13	14	7	10	11	91	49
19	92,5	86	32	93	14	72	21	74	81	100	35	265	153	68	5	13	153	83	44	80	114	93	33	74	265	74	62	16
20	97,5	16	34	45	116	39	67	30	13	48	6	219	19	1	77	33	19	581	6	607	20	30	38	30	219	14	311	18
Max periodic change		**318**	**133**	**813**	**281**	**92**	**82**	**1001**	**127**	**762**	**136**	**265**	**1924**	**108**	**103**	**160**	**1924**	**581**	**196**	**607**	**115**	**123**	**244**	**1001**	**265**	**130**	**311**	**99**

Table 27. Total area (ha) being thinned per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	2,5	139	134	141	134	167	134	149	171	136	197	136	170	171	150	150	170	204	171	200	167	167	170	146	133	167	138	163
2	7,5	155	165	155	196	205	196	181	209	162	204	155	198	213	192	204	198	250	213	245	211	217	198	177	152	193	160	204
3	12,5	148	157	234	186	185	173	151	165	234	195	226	243	187	184	173	243	171	177	171	193	188	243	147	221	154	227	157
4	17,5	318	293	378	332	355	369	312	378	372	350	386	352	354	328	341	352	386	367	382	358	354	352	305	378	298	336	313
5	22,5	325	363	309	357	472	336	332	266	317	295	288	367	309	360	352	367	423	297	423	300	304	367	325	282	331	327	309
6	27,5	395	399	377	465	452	461	395	452	377	450	387	460	457	439	460	460	415	456	411	484	490	460	386	379	414	370	414
7	32,5	300	287	393	320	286	341	300	346	393	354	398	480	346	353	311	480	419	336	419	362	356	480	294	390	285	408	290
8	37,5	343	463	360	395	438	424	336	488	354	485	366	322	496	409	417	322	311	521	311	475	471	322	329	359	434	291	437
9	42,5	321	315	298	420	413	361	316	251	296	276	307	298	253	331	317	298	367	239	367	260	264	303	310	301	290	320	278
10	47,5	368	445	404	337	330	331	373	482	409	460	354	494	454	334	390	494	446	503	446	540	540	506	366	346	451	393	460
11	52,5	245	186	291	273	282	276	233	256	282	243	293	202	262	356	314	202	230	256	230	198	198	205	228	287	184	232	187
12	57,5	170	193	128	143	97	135	178	121	133	208	120	84	120	111	117	84	130	127	130	191	189	137	174	117	213	161	199
13	62,5	110	152	285	45	118	106	85	108	224	200	113	125	90	45	68	125	125	117	125	124	143	141	83	110	157	173	102
14	67,5	74	184	160	277	196	299	76	368	238	316	438	190	395	302	295	190	237	366	237	296	309	180	74	429	302	323	220
15	72,5	222	378	254	291	161	264	223	298	228	286	782	27	319	300	287	27	168	298	160	228	226	14	219	765	135	682	343
16	77,5	102	246	29	253	117	120	152	310	30	341	114	84	276	266	263	84	102	307	90	111	116	16	149	112	282	167	182
17	82,5	303	134	129	236	163	291	273	313	64	308	11	155	355	286	287	155	707	312	707	186	209	211	267	11	293	100	256
18	87,5	189	103	28	180	335	336	211	277	28	206	28	66	298	227	224	66	51	242	51	184	204	221	206	27	201	26	113
19	92,5	170	234	1	147	196	94	187	115	1	193	1	123	129	104	122	123	156	134	116	318	293	341	183	1	228	1	256
20	97,5	266	378	470	119	167	128	260	93	480	201	28	145	82	109	110	146	100	111	90	284	330	243	254	27	280	29	379
	Mean value	**233**	**260**	**241**	**255**	**257**	**259**	**236**	**273**	**238**	**288**	**247**	**229**	**278**	**259**	**260**	**229**	**270**	**278**	**266**	**274**	**278**	**256**	**231**	**241**	**265**	**243**	**263**

Table 28. Total area (ha) being cleared per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	2,5	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	235	235	235	235	235
2	7,5	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	97	97	97	97	97
3	12,5	20	40	17	40	48	43	20	40	17	40	17	19	40	43	43	19	17	40	17	24	24	22	20	17	36	17	40
4	17,5	30	34	27	50	40	48	25	40	27	40	27	23	40	40	40	23	29	39	29	52	52	25	25	26	37	26	37
5	22,5	197	196	381	201	261	232	178	201	371	198	331	187	202	207	208	187	285	200	285	193	194	200	174	324	181	305	196
6	27,5	128	264	370	273	228	272	135	275	391	273	845	92	281	288	290	92	791	279	791	311	298	170	132	827	209	826	258
7	32,5	34	353	32	344	152	193	48	381	13	376	768		375	345	335		726	375	726	370	379	88	47	752	267	704	388
8	37,5	244	356	23	286	349	473	264	363	61	394	162	11	358	361	365	11	370	380	350	356	391	213	258	158	343	151	341
9	42,5	194	274	300	235	299	264	208	412	311	397	33	32	399	339	319	32	144	379	132	410	416	231	203	33	373	33	380
10	47,5	213	274	260	228	178	250	225	344	221	328	86	142	390	334	327	142	245	352	170	346	367	340	220	84	274	84	331
11	52,5	315	238	126	195	187	183	329	300	151	328	7	155	278	157	162	155	154	323	98	288	229	487	322	7	356	20	272
12	57,5	335	196	275	113	221	105	353	216	311	236	21	759	216	112	124	759	107	282	50	187	306	379	345	21	284	26	171
13	62,5	425	255	350	259	274	246	465	170	325	184	12	701	187	158	193	701	8	199	8	106	126	129	455	12	226	19	236
14	67,5	285	288	114	237	148	184	286	197	116	239	116	277	251	175	192	277	58	220	37	111	153	139	280	114	297	110	231
15	72,5	95	81	51	122	117	118	115	80	51	103	13	76	120	167	165	76	18	78	18	69	61	84	112	13	113	12	88
16	77,5	210	93	129	184	185	176	204	296	133	239	140	151	247	223	203	151	159	275	221	231	234	132	200	137	254	137	215
17	82,5	91	86	50	178	105	123	112	252	38	182	5	38	226	227	224	38	109	174	109	121	125	44	110	5	113	5	123
18	87,5	289	160	100	168	191	204	272	198	107	267	94	94	152	184	200	94	215	159	221	119	119	96	266	92	204	92	137
19	92,5	162	134	82	136	131	134	155	261	83	232	82	72	252	146	163	72	368	281	364	242	257	73	152	80	82	80	93
20	97,5	182	83	235	254	264	293	191	289	226	280	178	240	251	228	192	240	381	332	381	417	431	230	187	175	213	175	63
Mean value		**189**	**187**	**163**	**192**	**186**	**194**	**196**	**233**	**165**	**234**	**164**	**170**	**230**	**204**	**204**	**170**	**226**	**235**	**217**	**215**	**225**	**171**	**192**	**160**	**210**	**158**	**197**

Table 29. Total area (ha) being clear-cut per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	2,5	58	273	307	302	208	313	42	284	300	280	1680	8	284	307	305	8	1588	288	1588	372	371	50	41	1645	190	1609	285
2	7,5	47	365	106	323	393	331	26	365	111	367	41		374	359	349		70	369	70	361	359	169	25	40	254	8	351
3	12,5	222	351	113	299	263	366	278	469	109	473	4		454	405	410		50	469	27	432	437	308	272	4	375	11	439
4	17,5	204	315	298	294	226	256	214	436	302	438	5		454	381	383		56	425	34	389	425	294	209	5	398	5	392
5	22,5	150	104	295	99	207	149	149	111	293	97			79	46	44		22	99	15	152	84	301	146		155		79
6	27,5	239	106	299	94	220	144	259	156	308	173			136	97	91		30	164	30	123	174	298	254		142		135
7	32,5	803	316	302	333	203	186	856	205	298	192	157	1713	211	245	244	1713	120	194	114	96	82	300	838	154	368	161	263
8	37,5	78	125	70	83	70	83	90	86	74	87	70	70	82	64	78	70	18	71	18	44	44	70	88	68	155	68	107
9	42,5	62	87	56	55	56	82	70	55	56	57	57	56	55	63	51	56	22	51	44	45	40	56	68	56	89	56	77
10	47,5	90	44	38	78	57	44	96	93	38	91	42	38	91	52	48	38	36	133	58	80	80	38	94	41	90	46	83
11	52,5	55	80	19	57	88	69	75	165	19	173	19	21	149	51	61	21	94	126	107	127	140	24	74	19	177	19	116
12	57,5	124	105	77	112	124	135	111	101	78	103	40	78	126	102	89	78	80	119	80	106	111	86	109	39	78	35	112
13	62,5	170	151	17	135	82	115	166	208	17	202	15	17	200	158	168	17	285	212	285	174	174	17	162	15	125	14	112
14	67,5	217	105	208	185	200	195	209	392	197	402	45	45	376	203	201	45	434	384	434	399	413	54	205	44	110	44	103
15	72,5	239	155	293	133	123	121	262	96	301	105	78	129	81	107	106	129	95	100	95	114	101	181	256	76	157	76	169
16	77,5	180	230	307	120	138	144	164	98	302	88	99	99	101	123	124	99	63	79	63	96	107	115	161	97	175	97	217
17	82,5	105	196	295	128	143	136	103	82	305	62	149	133	74	231	123	133	43	72	43	92	75	260	101	146	229	146	230
18	87,5	85	213	300	203	154	169	86	49	302	66	189	151	47	149	192	151	123	59	123	74	78	291	84	185	192	185	269
19	92,5	102	445	301	167	251	199	87	105	297	105	460	404	105	150	208	404	100	100	100	102	86	296	85	450	368	450	446
20	97,5	258	630	306	333	324	299	273	103	302	109	2547	731	121	274	279	731	1926	97	1926	134	134	312	267	2493	424	2444	523
Mean value		**174**	**220**	**200**	**177**	**176**	**177**	**181**	**183**	**201**	**184**	**285**	**185**	**180**	**178**	**178**	**185**	**263**	**181**	**263**	**176**	**176**	**176**	**177**	**279**	**213**	**274**	**225**

Table 30. Total area (ha) being fertilized per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	2,5	256	233	54	287	276	301	324	113	65	113	49	43	131	205	175	43	71	123	71	126	123	319	317	48	99	43	107
2	7,5	192	233	298	242	265	247	206	55	345	55	92	75	55	83	81	75	106	55	106	69	69	274	202	90	80	84	54
3	12,5	217	152	243	169	284	172	241	70	279	66	98	134	70	85	87	134	141	70	141	92	89	369	236	96	82	93	68
4	17,5	384	191	387	257	357	240	409	81	429	76	164	225	96	136	136	225	174	84	174	137	137	497	400	161	100	101	102
5	22,5	520	323	389	304	316	324	668	105	418	101	282	1438	89	158	153	1438	288	109	288	127	129	446	654	276	98	100	132
6	27,5	227	246	291	293	331	319	244	69	299	80	312	225	87	203	202	225	205	75	205	96	90	225	239	305	99	108	118
7	32,5	293	242	256	340	360	275	297	64	263	62	220	235	65	269	208	235	256	60	256	134	127	237	291	216	110	98	110
8	37,5	316	328	294	257	274	261	352	60	296	60	315	409	76	230	201	409	320	60	320	106	99	409	344	308	100	106	107
9	42,5	224	187	207	224	156	218	257	35	209	46	220	158	40	158	170	158	158	36	158	30	30	160	251	216	41	96	39
10	47,5	213	202	144	140	149	152	243	73	182	94	144	134	106	134	139	134	140	73	140	71	73	134	237	141	72	85	72
11	52,5	196	213	267	224	209	248	207	30	215	59	94	112	51	135	175	112	353	30	353	71	71	109	203	92	17	94	129
12	57,5	241	188	211	265	302	310	276	324	343	316	458	182	414	311	203	182	546	297	546	305	196	182	270	449	108	90	186
13	62,5	357	418	497	362	236	346	389	315	514	318	840	158	298	370	203	158	180	298	180	188	144	158	381	822	80	95	321
14	67,5	194	387	301	401	272	306	222	258	332	236	190	155	256	374	199	155	164	241	164	94	82	155	217	186	101	109	211
15	72,5	386	282	370	284	266	311	356	165	342	135	139	196	130	357	189	196	214	163	214	95	77	379	349	137	96	98	327
16	77,5	239	303	260	257	397	337	271	104	271	97	163	194	103	191	203	194	123	97	123	121	106	498	266	160	100	89	316
17	82,5	266	529	470	148	319	150	290	49	548	55	640	632	40	137	208	632	213	60	213	133	79	742	284	626	93	85	487
18	87,5	373	719	725	289	242	227	390	18	777	18	2303	706	8	259	208	706	1342	66	1335	194	196	398	381	2254	105	95	541
19	92,5	192			962	941	1005	202	1080		1076		643	1114	1059	200	643	117	1113	117	952	196	651	198		96		
20	97,5	139			269	290	320	171	179		179		1	163	172	198	1	45	145	45	109	214	164	167		104		
Mean value		**271**	**269**	**283**	**299**	**312**	**303**	**301**	**162**	**306**	**162**	**336**	**303**	**170**	**251**	**177**	**303**	**258**	**163**	**257**	**163**	**116**	**325**	**294**	**329**	**89**	**83**	**171**
Total area		5426	5376	5664	5974	6241	6066	6014	3246	6125	3241	6725	6055	3390	5027	3538	6055	5156	3256	5148	3251	2329	6505	5888	6583	1781	1669	3248

Table 31. Total area (ha) with old forest (forest more than 120 years) per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values and standard deviations (S.D.) are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0	0	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101	2101
1	2,5	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192
2	7,5	2162	1984	1843	1960	2033	1944	2178	1980	1841	1984	905	2186	1980	1957	1959	2186	919	1976	919	1876	1877	2168	2179	933	2065	945	1981
3	12,5	2201	1683	1840	1748	1830	1724	2251	1696	1825	1683	912	2277	1687	1690	1702	2277	918	1690	918	1600	1605	2126	2253	942	1888	954	1711
4	17,5	2035	1483	1766	1522	1647	1476	2023	1355	1755	1359	922	2331	1361	1413	1427	2331	918	1354	918	1291	1289	1940	2030	952	1635	965	1404
5	22,5	1950	1275	1620	1321	1490	1313	1931	1137	1600	1137	937	2456	1125	1183	1185	2456	920	1133	920	1096	1070	1764	1943	970	1341	982	1182
6	27,5	1870	1217	1448	1304	1367	1227	1853	1055	1432	1050	956	2586	1057	1145	1151	2586	734	1043	872	1001	971	1526	1870	991	1226	1012	1109
7	32,5	1740	1111	1242	1310	1184	1136	1704	942	1217	905	1050	2714	929	1072	1100	2714	725	879	904	917	789	1330	1726	1086	1128	1106	1030
8	37,5	934	805	1009	933	970	924	882	740	987	710	939	916	717	839	829	916	603	662	799	803	620	916	923	979	795	983	769
9	42,5	883	760	959	881	900	874	829	720	937	685	887	855	696	804	778	855	589	636	800	790	591	855	873	929	734	932	744
10	47,5	880	784	952	872	889	860	822	740	931	703	875	843	708	812	800	843	590	655	807	800	607	843	867	919	758	922	764
11	52,5	883	801	964	883	891	874	818	750	940	713	879	841	718	815	805	841	606	665	793	805	618	841	864	924	765	927	775
12	57,5	922	844	992	912	920	905	826	762	968	727	899	866	749	854	843	866	627	678	801	820	632	866	872	944	788	947	806
13	62,5	913	854	985	903	911	896	836	767	961	731	891	856	738	845	833	856	629	684	803	825	638	856	883	937	799	941	816
14	67,5	955	895	1032	951	942	924	876	767	1006	730	934	901	746	887	875	901	629	684	803	831	644	901	923	979	794	986	850
15	72,5	1095	988	1225	1131	1160	1108	1014	812	1230	776	1155	1147	787	1041	1019	1147	859	723	1033	987	814	1147	1067	1205	846	1242	914
16	77,5	1196	1122	1292	1211	1200	1197	1098	883	1259	841	1174	1150	852	1070	1040	1150	827	780	1005	1006	830	1150	1151	1225	915	1279	970
17	82,5	1163	1100	1285	1186	1214	1178	1064	936	1252	896	1185	1173	916	1073	1059	1173	787	830	965	1010	820	1173	1122	1241	952	1295	984
18	87,5	1208	1145	1273	1191	1197	1186	1085	952	1234	910	1140	1096	926	1064	1048	1096	765	841	944	982	806	1096	1145	1199	985	1253	995
19	92,5	1313	1211	1388	1360	1347	1360	1188	1043	1349	1000	1418	1371	1067	1225	1209	1371	836	902	1018	1056	874	1288	1254	1479	1011	1526	1050
20	97,5	1525	1397	1398	1544	1549	1512	1414	1129	1357	1072	1579	1489	1124	1347	1314	1489	1010	1027	1192	1218	1042	1320	1492	1654	1180	1708	1205
Mean value		**1434**	**1226**	**1372**	**1305**	**1330**	**1281**	**1280**	**1117**	**1251**	**1091**	**1040**	**1540**	**1004**	**1211**	**1103**	**1540**	**794**	**1054**	**924**	**1143**	**920**	**1352**	**1316**	**1180**	**1086**	**1200**	**1060**
	S.D.	**515**	**439**	**386**	**409**	**422**	**411**	**541**	**472**	**363**	**486**	**323**	**688**	**434**	**430**	**394**	**688**	**347**	**506**	**306**	**432**	**449**	**495**	**522**	**377**	**457**	**381**	**412**

Table 32. Total area (ha) being regenerated under shelterwood per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	2,5			127	3	9	3		3	144	3	130	36	3	3	3	36	214	3	201	15	15	36		128		108	
2	7,5	6	10		10	24	10		10	16	10			10	17	17		92	7	92	32	29				3	6	10
3	12,5		8		6		6	6	31	2	31			31	6	6		31	34	31	46	50		6		14		26
4	17,5	6	7		14			6	31		51			57	7	12		45	61	45	62	61		6		36		26
5	22,5	70	78		32		45	70	112		100			102	75	70		212	121	74	103	138		69		86		96
6	27,5	18	74		27	51	55	18	56		88			104	69	52		30	131	11	40	129		18		72		61
7	32,5	121	104	19	127	98	109	121	103	19	108	19	211	97	91	130	211	21	149	21	123	171	211	118	19	124	32	128
8	37,5	2	1	1	3	22	1	2	21	1	18	1	55	18	45	46	55	19	8	4	1	13	55	2	1	42	1	20
9	42,5		14		4	6	9		14		17		5	23	3	3	5		14		16		5			14		14
10	47,5		61	5	10	14	25		65	5	69	5	50	69	38	58	50		62	10	5		50		5	63	5	63
11	52,5	17	9		50	19	45	17	26		41		4	56	57	57	4		16		2	2	4	17		25		9
12	57,5	3	2		12	22	2	3	47		27		4	12	35	31	4	5	41	5	5	5	4	3		29		2
13	62,5	10	8	7	114	102	114	10	92	7	25	7	8	88	114	114	8	7	81	7	11	11	8	10	7	32	7	8
14	67,5	96	41	6	52	38	36	103	68	6	135	6	6	73	73	68	6		33				6	101	6	43	6	42
15	72,5	33	21	22	26	26	22	27	23	22	23	22	26	19	38	46	26	26	13	22	8	22	26	26	22	20	22	30
16	77,5	37	17	77	105	106	117	37	34	77	54	77	77	60	50	41	77	77	47	77	77	77	77	36	75	70	75	29
17	82,5	39	66	53	3	25	4	39	20	53	3	53	78	18	22	22	78	49	32	49	49	49	78	39	52	36	52	56
18	87,5	47	160	36	1	6	3	47	30	36	41	34	95	39	9	7	95	59	49	56	31	31	95	46	33	45	192	158
19	92,5	145	48	347	9	25	9	145	39	381	39	354	219	41	15	16	219	233	55	221	123	123	219	142	346	43	160	47
20	97,5	27	32	48	48	60	48	27	21	49	25	48	10	26	19	19	10	344	69	344	135	139	10	26	47	45	61	57
Mean value		**34**	**38**	**37**	**33**	**33**	**33**	**32**	**42**	**39**	**45**	**36**	**44**	**45**	**39**	**39**	**44**	**70**	**51**	**61**	**44**	**51**	**44**	**32**	**37**	**40**	**36**	**42**

Table 33. Total volume (in 1000 m^3sk) of scots pine per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values and standard deviations (S.D.) are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1	2,5	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111
2	7,5	124	119	119	118	116	118	124	118	119	118	116	123	118	118	118	123	119	119	120	121	121	123	124	116	119	117	119
3	12,5	142	135	134	132	128	131	145	134	134	133	136	143	134	134	134	143	137	134	138	137	137	143	145	136	135	137	134
4	17,5	162	151	146	151	149	150	162	145	146	146	150	162	145	149	148	162	156	145	156	152	152	153	162	151	151	152	148
5	22,5	183	169	165	168	169	168	183	160	165	160	170	184	161	166	166	184	177	160	177	165	166	172	183	171	167	173	165
6	27,5	199	181	184	182	186	185	200	174	186	174	194	205	175	180	179	205	195	174	196	184	184	191	200	195	179	194	178
7	32,5	215	192	202	193	199	197	215	186	203	186	217	224	185	191	190	224	217	186	218	201	200	208	216	218	190	219	190
8	37,5	204	203	209	205	211	204	202	193	209	193	218	200	194	199	198	200	215	194	216	211	207	202	204	219	198	217	198
9	42,5	217	209	226	217	225	213	215	196	227	196	243	216	197	208	208	216	247	197	248	221	219	220	217	245	205	242	205
10	47,5	232	213	253	234	243	228	232	206	254	205	277	228	207	223	223	228	280	208	280	237	236	235	234	278	205	274	209
11	52,5	243	220	277	250	260	250	243	217	278	217	305	239	219	246	243	239	307	220	307	257	257	251	246	306	210	300	217
12	57,5	253	236	292	262	276	262	254	240	294	235	323	253	236	262	257	253	337	243	335	288	290	270	257	324	227	319	238
13	62,5	258	243	306	274	290	274	257	253	308	241	351	267	245	277	271	267	373	258	370	309	312	289	260	352	235	343	252
14	67,5	275	265	328	276	293	274	276	267	334	259	386	291	255	284	275	291	409	281	404	341	345	316	279	387	258	373	277
15	72,5	264	279	339	262	293	272	266	274	342	263	402	310	255	270	265	310	435	299	429	360	365	335	270	403	261	390	289
16	77,5	252	279	330	259	290	272	251	281	334	271	367	314	266	265	257	314	444	308	436	376	380	340	256	369	274	370	285
17	82,5	261	292	331	256	291	271	263	286	335	272	373	329	268	268	265	329	464	323	454	394	401	357	268	375	271	376	296
18	87,5	255	288	330	260	289	276	258	283	336	286	382	332	279	272	274	332	439	330	428	404	410	357	263	385	284	383	297
19	92,5	256	264	311	272	292	280	260	292	318	296	377	325	288	276	278	325	437	333	424	400	406	333	265	380	284	349	281
20	97,5	241	253	243	282	292	292	243	313	245	316	308	271	311	288	290	271	398	342	385	377	386	269	250	313	286	309	271
Mean value		**212**	**210**	**235**	**213**	**224**	**216**	**212**	**211**	**237**	**208**	**262**	**230**	**207**	**214**	**212**	**230**	**285**	**222**	**283**	**255**	**256**	**237**	**215**	**264**	**207**	**259**	**212**
	S.D.	**55**	**61**	**83**	**61**	**71**	**64**	**55**	**67**	**85**	**65**	**104**	**74**	**63**	**64**	**62**	**74**	**128**	**80**	**124**	**105**	**108**	**84**	**57**	**105**	**60**	**101**	**66**

Table 34. Total volume (in 1000 m^3sk) of broadleaf per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values and standard deviations (S.D.) are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0	0	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84
1	2,5	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
2	7,5	101	96	94	96	97	95	100	94	94	94	59	101	94	95	95	101	57	94	58	92	92	101	100	60	96	60	94
3	12,5	112	98	105	99	96	95	110	94	103	95	66	113	94	95	95	113	56	94	57	91	91	109	110	67	99	71	95
4	17,5	113	96	109	98	97	95	113	91	107	90	72	121	91	93	93	121	59	91	61	87	87	110	113	74	99	76	92
5	22,5	113	93	104	96	96	95	112	79	103	79	76	129	79	88	88	129	61	79	64	76	75	111	113	78	92	81	84
6	27,5	115	94	103	100	96	95	114	81	100	81	84	138	81	93	93	138	62	80	67	74	75	109	115	85	92	89	87
7	32,5	113	95	99	104	96	95	112	79	96	78	85	150	80	96	96	150	61	75	66	71	68	107	114	87	93	90	87
8	37,5	87	85	90	92	96	95	79	69	87	69	76	86	69	87	87	86	57	64	62	67	63	93	81	78	77	81	74
9	42,5	88	83	90	94	96	95	78	67	87	68	73	88	69	87	85	88	58	64	63	68	64	93	81	76	70	79	70
10	47,5	90	86	93	94	96	94	79	70	90	70	76	91	71	88	87	91	63	68	67	70	67	94	82	79	71	82	72
11	52,5	92	84	95	97	99	95	80	68	92	69	80	93	69	86	84	93	65	64	68	69	65	92	83	83	69	86	69
12	57,5	91	87	96	97	100	97	80	66	92	66	82	96	67	86	86	96	66	64	68	68	66	90	83	85	68	88	71
13	62,5	92	90	94	101	101	101	80	69	90	70	84	95	71	90	89	95	70	67	72	72	68	91	84	88	71	90	75
14	67,5	90	91	96	103	101	101	78	73	92	73	90	92	74	93	91	92	74	71	77	76	73	94	82	94	74	95	77
15	72,5	85	91	94	102	101	101	73	74	92	75	91	92	75	93	92	92	74	73	77	78	74	95	78	95	73	97	79
16	77,5	85	90	90	100	102	101	74	76	86	77	86	93	77	93	93	93	78	74	81	79	75	96	78	90	75	94	79
17	82,5	84	87	85	98	101	101	73	77	81	79	81	91	79	91	92	91	78	75	81	80	77	95	78	85	75	88	77
18	87,5	85	88	86	97	101	101	75	80	83	82	81	90	81	89	91	90	76	78	78	83	79	93	80	86	78	89	79
19	92,5	85	89	91	100	101	101	75	83	87	85	85	95	84	92	93	95	79	80	82	85	82	94	80	90	79	92	80
20	97,5	87	90	92	101	102	102	77	84	88	86	83	92	86	94	94	92	78	82	80	84	82	91	82	88	82	90	81
Mean value		**94**	**90**	**94**	**97**	**98**	**97**	**87**	**78**	**92**	**79**	**80**	**101**	**79**	**91**	**90**	**101**	**69**	**77**	**72**	**78**	**76**	**97**	**90**	**83**	**81**	**85**	**81**
	S.D.	**12**	**4**	**7**	**5**	**4**	**4**	**15**	**9**	**7**	**9**	**8**	**18**	**9**	**4**	**4**	**18**	**10**	**10**	**9**	**8**	**9**	**8**	**14**	**9**	**11**	**9**	**8**

Table 35. Total net income (in 10000 SEK) per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values and standard deviations (S.D.) are per period. To get the net income the first period: sum the value of period 0 with the value given in period 1.

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0	0	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149	-149
1	2,5	-102	294	-60	307	131	305	-141	354	-91	352	339	-185	348	344	350	-185	291	350	316	350	353	-257	-138	332	238	372	348
2	7,5	13	260	-35	249	186	250	-60	308	-15	310	-44	-55	316	302	299	-55	-98	314	-104	299	291	-141	-59	-43	250	-58	299
3	12,5	273	232	-79	188	168	213	437	283	-74	283	-53	-142	282	253	248	-142	-151	287	-136	247	255	36	428	-52	274	-44	252
4	17,5	273	229	326	218	229	200	274	255	354	254	-36	-72	257	217	218	-72	-25	248	-28	218	212	125	268	-35	326	-18	222
5	22,5	387	287	450	244	241	237	359	246	369	241	-15	-276	237	211	213	-276	63	235	52	185	183	383	352	-15	334	27	252
6	27,5	592	320	465	283	298	251	617	270	550	262	-13	159	262	245	241	159	11	263	18	212	206	823	604	-13	369	36	293
7	32,5	1408	376	1036	288	332	311	1451	299	1042	287	553	3725	288	273	280	3725	599	287	516	229	245	1407	1420	542	408	546	332
8	37,5	287	443	363	350	374	344	300	326	353	320	338	298	318	309	327	298	99	304	95	296	287	263	293	331	461	326	383
9	42,5	416	500	255	403	433	466	397	349	256	346	290	532	342	399	403	532	247	343	308	315	323	499	389	284	507	291	444
10	47,5	663	574	322	531	494	387	683	393	318	383	372	422	384	407	411	422	258	375	303	370	359	387	669	364	547	369	499
11	52,5	676	567	468	476	580	473	717	425	478	424	544	411	424	470	510	411	562	432	638	389	465	361	702	532	608	522	595
12	57,5	819	781	630	596	656	655	796	476	614	475	341	386	476	591	550	386	458	508	502	525	519	449	779	334	619	414	697
13	62,5	1216	997	51	741	703	666	1178	503	40	506	-39	112	505	624	627	112	1453	493	1479	517	503	203	1154	-38	702	140	747
14	67,5	1699	972	485	725	830	823	1726	581	531	568	379	210	531	741	792	210	1104	522	1113	654	643	267	1690	371	851	289	862
15	72,5	1879	1134	1431	934	1009	939	1942	626	1455	592	1340	1033	617	870	883	1033	780	630	799	757	732	1046	1902	1312	823	1043	1047
16	77,5	1072	1350	1996	1208	1148	1183	981	751	2010	696	926	688	752	990	942	688	603	600	615	814	875	643	960	906	936	824	1157
17	82,5	1012	1516	2592	1204	1448	1196	963	835	2566	670	1232	1308	735	1216	1051	1308	1176	775	1186	1050	923	1576	943	1206	1306	1212	1360
18	87,5	767	1701	1950	1364	1482	1254	791	786	1949	873	1459	1804	745	1302	1388	1804	1048	767	1055	1158	1140	2596	775	1428	1191	2262	1547
19	92,5	1242	2055	4068	1584	1759	1648	1192	923	4164	917	4989	4555	918	1377	1517	4555	1845	899	1844	1308	1302	4045	1167	4884	1200	3953	1763
20	97,5	1010	2308	3009	1910	2065	1858	1057	1010	3027	995	11893	3579	1012	1696	1748	3579	7720	1001	7717	1510	1489	2376	1035	11642	1435	9049	2061
Mean value		**773**	**837**	**979**	**683**	**721**	**676**	**775**	**493**	**987**	**480**	**1232**	**917**	**480**	**634**	**642**	**917**	**895**	**474**	**907**	**563**	**558**	**847**	**759**	**1206**	**662**	**1070**	**750**
	S.D.	**563**	**661**	**1155**	**531**	**593**	**524**	**571**	**275**	**1169**	**268**	**2693**	**1397**	**267**	**473**	**487**	**1397**	**1669**	**262**	**1666**	**422**	**411**	**1071**	**559**	**2636**	**407**	**2066**	**576**

Table 36. Volume dead wood per hectare ($m^3 sk/ha$), per period and management plan. One period is 5 years and the values are given in the middle of each period. The mean values and standard deviations (S.D.) are per period

Period	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	2,5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	7,5	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	1	2	1	2	2	2	2	1	2	1	2
3	12,5	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	2	3	2	3	3	3	3	2	3	2	3
4	17,5	5	4	5	4	4	4	5	4	5	4	3	5	4	4	4	5	3	4	3	4	4	5	5	3	4	3	4
5	22,5	6	5	6	5	6	5	6	5	6	5	4	6	5	5	5	6	4	5	4	5	5	6	6	4	5	4	5
6	27,5	8	6	7	7	7	6	8	6	7	6	5	8	6	6	6	8	5	6	5	6	6	8	8	5	6	5	6
7	32,5	9	8	8	8	8	8	9	7	8	7	6	11	7	7	7	11	6	7	6	7	7	9	9	6	7	6	7
8	37,5	10	8	9	9	9	9	10	7	9	7	7	12	8	8	8	12	7	7	7	7	7	10	10	7	8	7	8
9	42,5	11	9	10	10	10	10	11	8	10	8	8	13	8	9	9	13	8	8	8	8	8	11	11	8	9	8	9
10	47,5	12	10	11	11	11	11	12	9	11	9	9	13	9	10	10	13	8	9	9	9	9	12	12	9	10	9	9
11	52,5	13	11	12	12	12	12	13	10	12	10	10	14	10	11	11	14	9	9	10	10	10	13	13	11	10	10	10
12	57,5	13	12	13	13	13	13	13	10	13	10	11	15	11	12	12	15	10	10	11	10	10	14	14	12	11	11	11
13	62,5	14	13	14	14	14	14	14	11	14	11	13	16	11	13	13	16	12	11	12	11	11	15	15	13	12	13	12
14	67,5	15	14	16	15	16	15	15	12	16	12	14	17	12	14	14	17	13	12	13	12	12	16	16	14	13	14	13
15	72,5	16	15	17	16	17	16	16	13	17	13	16	18	13	16	16	18	14	13	14	13	13	18	16	16	13	15	13
16	77,5	16	15	18	17	18	17	16	13	18	13	17	19	14	17	17	19	15	13	15	14	14	19	17	17	14	17	14
17	82,5	17	16	19	18	19	18	16	14	19	14	18	20	14	18	17	20	15	14	16	15	14	20	17	19	14	18	15
18	87,5	17	16	19	19	19	19	16	15	20	14	20	21	15	18	18	21	16	14	17	15	15	21	17	20	15	19	15
19	92,5	17	17	20	20	20	19	16	15	20	15	22	22	16	19	19	22	17	15	18	16	16	22	17	22	15	20	16
20	97,5	17	17	20	20	21	20	16	16	20	16	23	22	16	20	19	22	18	16	19	17	16	22	17	24	15	21	16
Mean value		**11**	**10**	**12**	**11**	**11**	**11**	**11**	**9**	**12**	**9**	**11**	**13**	**9**	**11**	**11**	**13**	**9**	**9**	**9**	**9**	**9**	**12**	**11**	**11**	**9**	**10**	**9**
	S.D.	**5**	**5**	**6**	**6**	**6**	**6**	**5**	**5**	**6**	**5**	**7**	**7**	**5**	**6**	**6**	**7**	**6**	**5**	**6**	**5**	**5**	**7**	**6**	**7**	**5**	**7**	**5**

Appendix 7

Table 37-38 shows the values of the ideal solutions of every management plan.

Table 37.The ideal solutions for the management plans (MP) 1-14.

Ideal solutions	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Netto, mean value (SEK)	7222220	7219423	8282601	5871727	6175742	5826330	7226440	4420533	8360273	4306363	6376044	7382056	4294499	5496219
Netto, S.D. (SEK)	5524291	6486956	11653313	5178311	5843414	5116067	5617449	2488719	11796991	2415126	27482653	14195738	2408349	4579230
Periodic change in clear-cut area (%)	318	133	813	281	92	82	1001	127	762	136	265	1924	108	103
Fertilized area, mean value (ha)	271	269	283	299	312	303	301	162	306	162	336	303	170	251
Thinned area, mean value (ha)	233	260	241	255	257	259	236	273	238	288	247	229	278	259
Area planted with lodgepole pine, mean value (ha)	24	33	27	28	28	28	25	30	27	31	30	24	29	28
Area planted with lodgepole pine, S.D. (ha)	26	21	36	20	25	17	28	16	35	15	44	31	17	24
Clear-cut area, mean value (ha)	174	220	200	177	176	177	181	183	201	184	285	185	180	178
Area of old forest, mean value (ha)	1434	1226	1372	1305	1330	1281	1280	1117	1251	1091	1040	1540	1004	1211
Area of old forest, S.D. (ha)	515	439	386	409	422	411	541	472	363	486	323	688	434	430
Area with continuous forest cover, mean value (ha)	329	329	329	329	644	476	801	521	942	441	811	619	429	616
Area with unmanaged forest (ha)	610	610	610	610	610	610	610	610	610	610	610	610	610	610
Area regenerated under shelterwood (ha)	34	38	37	33	33	33	32	42	39	45	36	44	45	39
Volume of dead wood, mean value (m^3sk/ha)	11	10	12	11	11	11	11	9	12	9	11	13	9	11
Volume of dead wood, S.D. (m^3sk/ha)	5	5	6	6	6	6	5	5	6	5	7	7	5	6
Volume broadleaf, mean value (m^3sk)	94433	89873	94209	97349	97547	96511	87403	78467	91572	78996	80155	100898	79342	90567
Volume broadlead, S.D. (m^3sk)	11501	4325	6682	4715	4319	4410	15406	8906	6843	8828	7999	18259	8596	3533
Volume scots pine, mean value(m^3sk)	211607	209568	235039	212552	223915	215649	212335	210887	236979	208416	262148	229730	207108	213588
Volume scots pine, S.D. (m^3sk)	54595	60932	82920	61132	70944	64186	54924	66637	84756	64818	104388	73696	62733	63849
Cleared area, mean value (ha)	189	187	163	192	186	194	196	233	165	234	164	170	230	204

Table 38 The ideal solutions for the management plans (MP) 15-27

	15	16	17	18	19	20	21	22	23	24	25	26	27
Netto, mean value (SEK)	5549484	7382056	5086289	4241048	5210701	4871475	4833100	7281777	7072716	6240223	5900131	6178521	6474383
Netto, S.D. (SEK)	4725775	14195599	16991424	2360159	16959060	4072861	3962410	10836986	5502337	26904620	3853178	21049932	5621577
Periodic change in clear-cut area (%)	160	1924	581	196	607	115	123	244	1001	265	130	311	99
Fertilized area, mean value (ha)	177	303	258	163	257	163	116	325	294	329	89	83	171
Thinned area, mean value (ha)	260	229	270	278	266	274	278	256	231	241	265	243	263
Area planted with lodgepole pine, mean value (ha)	28	24	24	28	24	27	27	27	25	29	33	29	35
Area planted with lodgepole pine, S.D. (ha)	23	31	33	15	33	19	20	31	27	43	21	44	21
Clear-cut area, mean value (ha)	178	185	263	181	263	176	176	176	177	279	213	274	225
Area of old forest, mean value (ha)	1103	1540	794	1054	924	1143	920	1352	1316	1180	1086	1200	1060
Area of old forest, S.D. (ha)	394	688	347	506	306	432	449	495	522	377	457	381	412
Area with continuous forest cover, mean value (ha)	609	619	324	352	506	470	294	619	791	801	542	855	552
Area with unmanaged forest (ha)	610	610	610	610	610	610	610	610	723	723	723	723	723
Area regenerated under shelterwood (ha)	39	44	70	51	61	44	51	44	32	37	40	36	42
Volume of dead wood, mean value (m^3sk/ha)	11	13	9	9	9	9	9	12	11	11	9	10	9
Volume of dead wood, S.D. (m^3sk/ha)	6	7	6	5	6	5	5	7	6	7	5	7	5
Volume broadleaf, mean value (m^3sk)	90394	100898	68903	76660	71592	78346	76024	96739	90025	82931	81354	85300	80756
Volume broadlead, S.D. (m^3sk)	3800	18259	10081	9956	9400	8141	9224	7753	13964	8670	10508	8616	7939
Volume scots pine, mean value(m^3sk)	211937	229730	285432	222128	282542	254558	256358	236808	214818	263583	207185	259447	212425
Volume scots pine, S.D. (m^3sk)	62487	73696	127753	79950	123844	105246	107904	84156	56600	105091	60293	100832	65628
Cleared area, mean value (ha)	204	170	226	235	217	215	225	171	192	160	210	158	197